New Scientist

WEEKLY 24 August 2024

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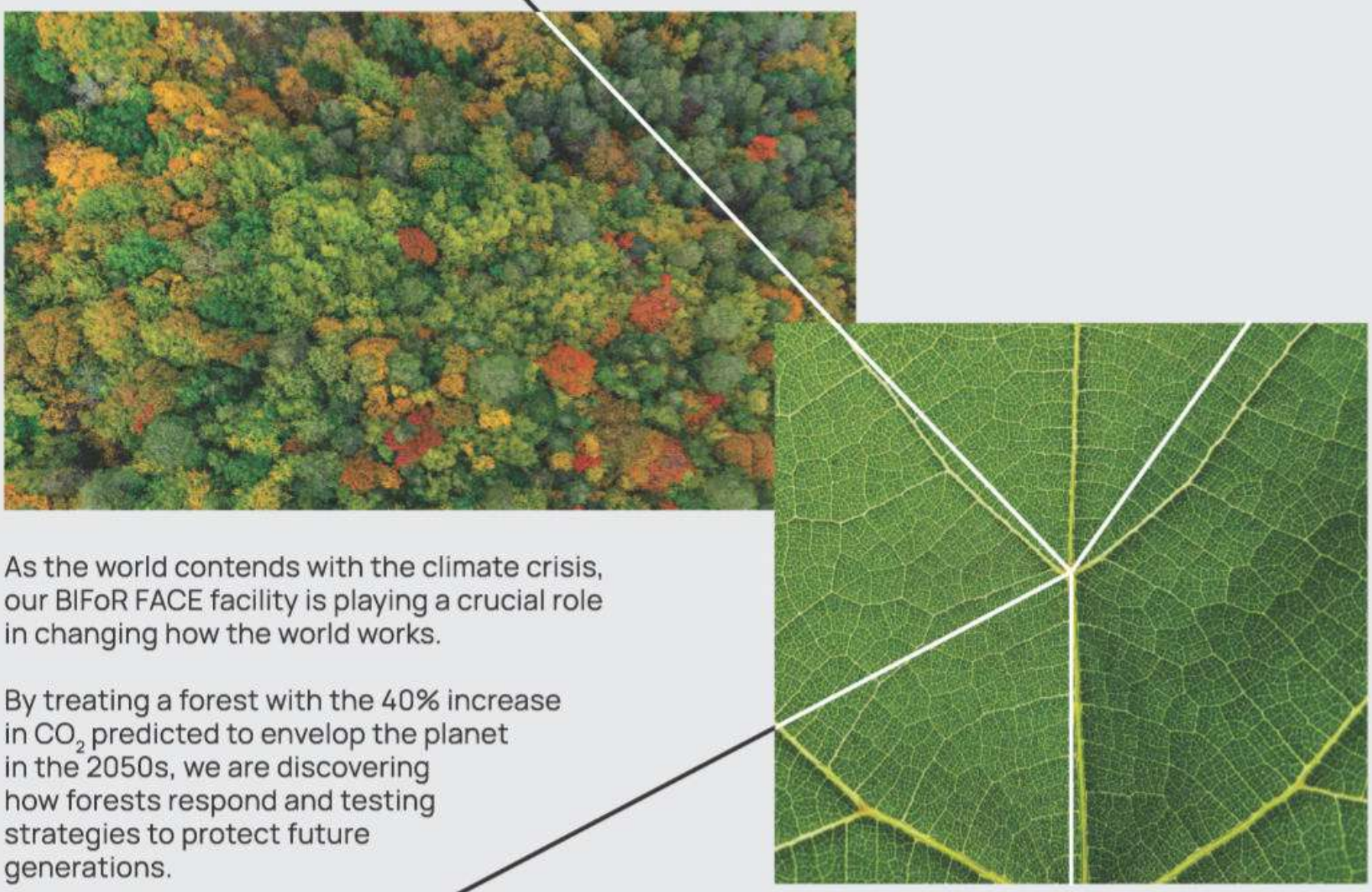

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Understanding humans

Our bodies are a wonder of evolution, but they are also deeply flawed. To help us understand the course humanity has taken – from prehistoric times through to the modern era – astrobiologist Lewis Dartnell explores who, and what, we are. Find out more on 13 October at New Scientist Live at London's ExCeL Centre or watch online.

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Tour

Retracing Charles Darwin's travels: Wales

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Podcast

CultureLab

New Scientist's TV columnist Bethan Ackerley offers her rundown of the top science TV shows from 2024 so far. From the genetically gifted superheroes of *Supacell* to a sobering documentary about the ethics of assisted dying, she has a wealth of options for your next night in. Plus, tips for upcoming shows to keep an eye out for.

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Frog life Drones keep an eye on endemic species in Madagascar

PAJOR PAWEL/SHUTTERSTOCK

In Darwin's footsteps Marvel at the landscape of Eryri (Snowdonia)

Video

Watching over nature

Madagascar is famous for its biodiversity, which is under strain through deforestation. Jenny Williams at the Royal Botanic Gardens, Kew, in London has been flying small drones over habitats to map where protected areas are being cleared. The models created from this data can estimate the carbon stored by the forest and alert authorities to illegal activity.

youtube.com/newscientist

Newsletter

Wild Wild Life

Until recently, many discounted the idea that life could have existed on Earth before 3.8 billion years ago because a heavy pummelling from asteroids at this time would have made this impossible. But did this bombardment really happen? Penny Sarchet looks at evidence pointing to an earlier origin of life.

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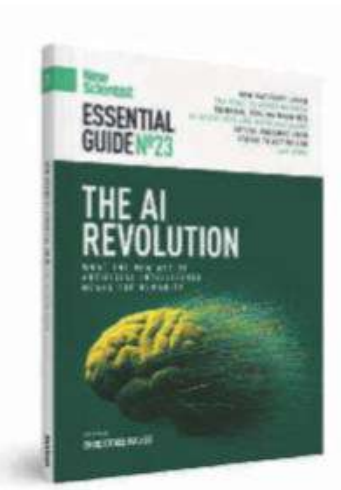
Newsletter

"Earth was a fiery, volcano-covered world that suffered constant collisions"



Essential guide

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RIP 1.5°C

Climate slogans get in the way of real conversations about what needs to be done

AS THE COP26 climate negotiations were taking place in Glasgow, UK, in November 2021, a new slogan entered the lexicon: "keep 1.5°C alive". The phrase, on the lips of everyone from politicians to climate scientists, aimed to preserve the goal set six years earlier as part of the Paris Agreement at COP21. In hindsight, this ambition was probably already dead, destined to be deployed only as an empty slogan.

New Scientist began making this argument in 2022, when the public sentiments of experts didn't reflect their private views or the data we were seeing. Scientists felt trapped, unable to speak out because limiting warming to 1.5°C above pre-industrial levels still remained possible according to the laws of physics, while being impossible with any realistic acknowledgment of the political, social and economic upheaval required.

In the intervening years, there has been a growing realisation that 1.5°C is out of reach, but not a frank conversation about what that means. Now, researchers have

"The phrase 'net zero' is used by many to mean 'an environmental policy I don't like'"

for the first time explicitly ruled it out, saying 1.6°C is the best we can hope for, while even higher temperatures are the more likely outcome (see page 6).

Will this finally be enough for policy-makers to sit up and realise that platitudes and slogans aren't a sufficient form of climate action? Promises to keep any such goal "alive" are pointless without doing the only thing that will prevent temperatures rising: reducing the amount of carbon dioxide and other planet-warming greenhouse gases entering the atmosphere to net zero.

Unfortunately, the phrase "net zero" is losing its true meaning as a description of atmospheric physics, instead being used by many to mean "an environmental policy I don't like". This is dangerous, as temperature extremes have us trapped in a vicious cycle of emissions that only a net-zero energy system can break (see page 7). If we are to have any hope of limiting warming, we must learn from the mistakes of "keep 1.5°C alive" and not let "net zero" become meaningless. ▮

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Earth science

Quake triggers a volcanic eruption

Shiveluch, one of Russia's most active volcanoes, has erupted, spewing ash 5 kilometres into the sky over the Kamchatka peninsula. This created a plume stretching 490 kilometres to the east and south-east. The activity followed a magnitude-7.0 earthquake off Kamchatka's coast, with volcanologists at the Russian Academy of Sciences saying that another tremor could be on the way.

VIKTOR FROLOV/@IVIS_DVO_RAN/COVER IMAGES

Climate change

1.6°C is now best-case scenario

It has become essentially impossible to hit the totemic climate goal of keeping warming to no more than 1.5°C above pre-industrial levels, says **Madeleine Cuff**

THE internationally agreed goal of limiting global warming to 1.5°C above pre-industrial levels is now almost certainly out of reach. Limiting warming to 1.6°C has become the best-case scenario for climate action, with the hope of bringing temperatures back to 1.5°C later in the century using technology to remove carbon dioxide from the atmosphere.

"1.5°C without overshoot is not attainable," says Christoph Bertram at the Potsdam Institute for Climate Research in Germany.

"The world does not end at 1.5°C. Every tenth of a degree matters in terms of the impacts to society"

"You definitely therefore need to prepare for one-tenth, or potentially multiple tenths, of a degree beyond that target."

Bertram and his colleagues came to this conclusion by running a series of models that accounted for realistic constraints in rolling out green technologies and implementing climate policies, as well as "enabling factors", such as a reduction in energy demand.

Green technologies like renewable energy have taken off in recent years, but the key constraint to rapid climate action is the ability of governments to roll out carbon-limiting policies such as carbon taxes, the team found. Some countries don't have the infrastructure or the bureaucracy to enforce policies like carbon pricing, says Bertram. "Even if we see a massive shift in the coming years politically, we still can't get around these hard facts," he says. "You can't expect all countries to have perfect regulation."

Once this is accounted for in modelling, the best-case scenario is limiting peak warming to 1.6°C, says Bertram. Even that will require huge political will from higher-income countries that have the greatest hope of taking climate action, he says. "We are very far from that world, politically."

In fact, the researchers say it is more likely than not that we won't be able to limit warming to 1.6°C. There are a wide range of uncertainties, but they calculate the chance of succeeding at between 5 and 45 per cent. Success rates increase at 1.7°C, 1.8°C and so on. "The world needs to be prepared for the possibility of an overshoot of the 1.5°C limit by at least one and probably multiple tenths of a degree even under the highest possible ambition," they write in their paper (*Nature Climate Change*, doi.org/ndb9).

Team member Joeri Rogelj at Imperial College London insists the paper shows "a relatively positive picture". He says the models suggest warming can be held below 2°C, if governments continue to improve their institutional capacities, and green technology is rolled out rapidly.

This latest study reflects the growing scientific consensus that the 1.5°C target, agreed by countries in Paris in 2015, is now unachievable without emissions overshoot. The last update from the Intergovernmental Panel on Climate Change released in 2022 suggested a narrow path to limiting warming to 1.5°C was still possible, but since then global emissions have risen.

AMER GHAZZAL/SHUTTERSTOCK

Global temperatures have already risen 1.26°C above pre-industrial levels

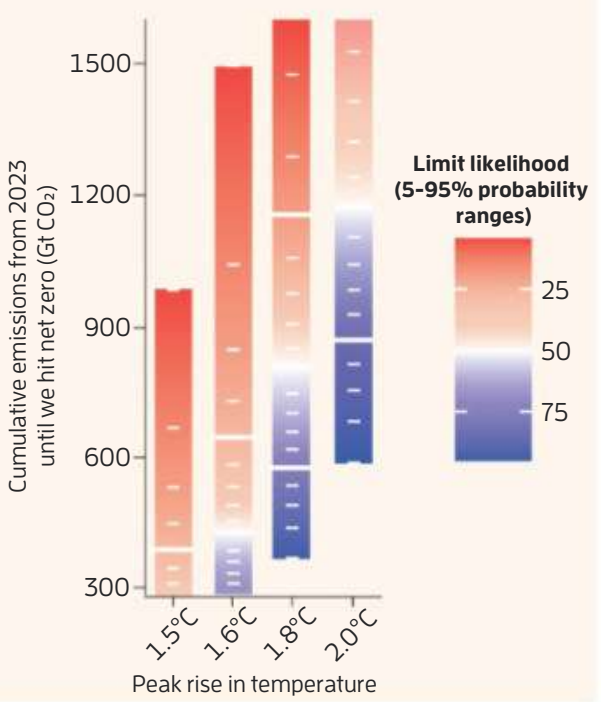
Human activities have already increased average global temperatures by 1.26°C above pre-industrial levels, with 2024 likely to be the first year that they surpass 1.5°C of warming.

Zeke Hausfather at US non-profit organisation Berkeley Earth says the paper "more or less states what has become a largely unspoken consensus in the community: that it's too late to prevent warming from exceeding 1.5°C". But he stresses that warming below 2°C is still plausible. "The world does not end at 1.5°C, and every tenth of a degree matters in terms of the impacts to society, the natural world and future generations."

"It puts that number, 1.6°C, out there," says Ryan Katz-Rosene at the University of Ottawa, Canada, "and that is what the debate is going to centre on now. And after 1.6°C, if we surpass that, it's going to be 1.7°C." ▮

Where will the warming stop?

The peak temperature rise the world experiences will depend on how much carbon dioxide is emitted before we reach net-zero emissions. Optimistic scenarios put this at 550 to 700 gigatonnes of CO_2 and pessimistic ones at 900 to 1000 GtCO_2, which corresponds to about a 75 per cent or 40 per cent probability of staying below 1.8 °C, respectively. The chances of limiting temperature rises to 1.6 °C currently sit at between about 5 and 45 per cent.



SOURCE: *NATURE CLIMATE CHANGE*, DOI.ORG/NDB9

Carbon emissions

Our efforts to cope with extreme temperatures are making them worse

WHEN temperatures turn extreme, we rush to adjust our heating or cooling systems in an attempt to remain comfortable. With severe weather events becoming ever more frequent due to climate change, so too does our fiddling with the thermostat, which, in turn, is causing spikes in daily carbon dioxide emissions, leading to yet more climate change. Failing to break this vicious cycle will mean the problem only gets worse.

Zhu Liu at Tsinghua University, China, and his colleagues have been tracking global daily CO_2 emissions since January 2019 to examine how seasonal cycles, time of the week, the weather and other factors influence them. They used data collected between 2019 and 2022 to train a machine-learning algorithm to estimate daily CO_2 emissions back in time to 1970, at a global level and at a national level for key countries.

The results, unsurprisingly, revealed a large increase in global daily CO_2 emissions from 1970 to 2022, from 50.6 million tonnes a day on average in 1970 to 106.9 million tonnes a day in 2022. We already know emissions have risen dramatically over the past 50 years as countries around the world have industrialised.

More interestingly, Liu's team also identified a previously overlooked trend in increasing emissions due to extreme hot and cold days, defined as days where temperatures fell below the 5th percentile or above the 95th percentile from 1970 to 2022 for each country.

For example, daily emissions during extremely cold days jumped by 11 per cent in Germany over the study period, compared with the average for the corresponding month, and emissions increased by 4 per cent in Japan during extremely hot days.

The increase in emissions due to extreme heat events accelerated over the 2010s, when the average number of days of extreme heat experienced each year more than doubled compared with the 1970s. Between 2019 and 2022, daily emissions during extreme hot days in Japan were 12.3 per cent higher compared with the monthly average, for example (arXiv, doi.org/ndbp). "More frequent extreme temperature is resulting in more emissions," says Liu.

He warns that the emissions spikes are a consequence of poor adaptation to a rapidly changing climate. This will create a feedback loop where extreme weather drives higher emissions, which then intensifies climate change. "It's definitely not good news for the world… it's difficult to break," he says. Even an accelerated switch to renewable energy isn't a complete solution, as power plants, including renewable energy units, become less efficient in extreme temperatures, leading to an uptick in fossil fuel use to make up the difference.

The team also identified a "critical temperature" for each country, where emissions are generally at their lowest level. In China this temperature is 19.5°C (67.1°F), in the US it is 15°C (59°F) and in Japan it is 18.2°C (64.8°F). For most countries,

"For most countries, when temperatures fall below or climb above a critical point, emissions start to rise"

when temperatures fall below or climb above this critical point, emissions start to increase.

Team member Glen Peters at the Center for International Climate Research in Norway says governments will need to consider the impact of increasingly extreme weather and the way people respond to more and more uncomfortable conditions when designing future energy systems. "If you have an increased demand for cooling, and more people buy air conditioners, then it can amplify the effects," he says.

"Worsening climate impacts can affect societal emissions of greenhouse gases that are driving the warming of climate in the first place," says Richard Allan at the University of Reading, UK, leading to a "vicious cycle" of escalating emissions. "The new study is the first to really dig into day-to-day fluctuations and construct regional relationships between long-term changes in emissions and temperature."

Joeri Rogelj at Imperial College London says the study underscores the need for urgent climate policies to cut emissions and ensure low-carbon adaptation. "It just shows the importance of going to net zero, both to limit the amount of heat extremes, but also to limit the amount of additional CO_2 that gets produced because of those heat extremes," he says.

One limitation of the work is that the data the researchers used to train their algorithm includes two years of the coronavirus pandemic, which saw emissions dip globally. The algorithm also doesn't account for differences between 1970s society and the present day. Levels of access to air conditioning, for example, were a lot lower in the 1970s, meaning extreme heat days would have had a lower emissions impact back then. Even so, Alp Kucukelbir at Columbia University in New York says using machine learning is a good way to "fill in" data we would have liked to have collected in the past.

Both Peters and Allan say that even with uncertainties around the precise figures, the general trend towards more extreme temperatures causing higher emissions is clear. "Despite limitations, the findings do amplify existing knowledge that global warming will make emissions reductions even more challenging," says Allan. ▮ MC

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Higher temperatures mean people crank up the air conditioning more often

Analysis Infectious diseases

Why is mpox a global emergency again so soon? Cases of mpox are rising rapidly not long after the last emergency was declared over. Carissa Wong reports on what's going on and how the spread can be stopped

JUST over a year after the last mpox outbreak was deemed to no longer be a global emergency, the World Health Organization (WHO) has once again sounded its highest alarm. On 14 August it declared Central Africa's current mpox surge a public health emergency of international concern (PHEIC).

Mpox, formerly known as monkeypox, is an infectious disease caused by a virus that belongs to the same family as the one that causes smallpox. It regularly spreads among animals in Central and West Africa, such as rodents and monkeys, but occasionally jumps to people, causing small outbreaks.

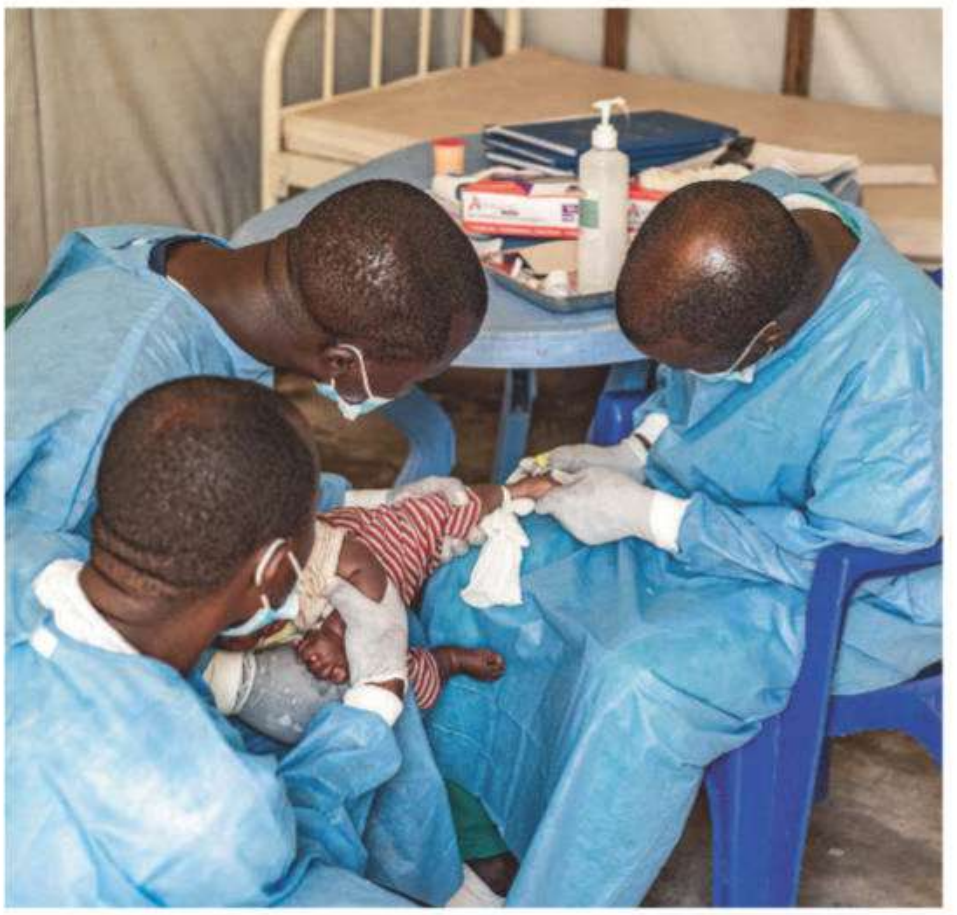
It was made a PHEIC for the first time in July 2022 as it spread rapidly across a range of countries where it hadn't been reported before.

Despite that emergency ending in May 2023, reported infections went on to increase significantly. The number tallied so far this year already exceeds 2023's total, with more than 15,600 cases and over 530 deaths in the Democratic Republic of the Congo (DRC).

The virus has also again spread beyond the Central and West African countries it is endemic in, with cases being reported in Kenya, Rwanda, Burundi and Uganda for the first time.

On 15 August, Swedish health officials confirmed an mpox case as the first known infection outside Africa with the subtype of the virus that is currently driving the outbreak in the DRC. An mpox case has also been detected in the Philippines, but the subtype that caused it isn't yet known.

So, how is mpox a global emergency again so soon after the last one? To answer this question, we need to look back to the WHO's first mpox PHEIC, which came after cases were reported in countries including the UK, US and Australia. The declaration led to these countries ramping up access to smallpox vaccines that work against the related mpox virus, which were targeted to those most at risk, including men who have sex with men.



XINHUA/SHUTTERSTOCK

A child with mpox is treated near Goma in the Democratic Republic of the Congo

These efforts helped cases to subside in these parts of the world. But in the DRC, where mpox was first identified in humans in 1970, vaccines were largely unavailable. This was due to a lack of funding and other countries not donating them, allowing the outbreak to persist, says Piero Olliaro at the University of Oxford.

This meant the virus could spread, mutate and evolve, which resulted in the emergence of a new version, or clade, of mpox.

NIAID

A coloured micrograph of an mpox virus particle (pink and yellow) inside an infected cell (green)

There are two main types of mpox: clade I and clade II. While these both circulate in Central and West Africa, a subtype of clade II drove the global outbreak in 2022, while the ongoing surge is due to a subtype of clade I, called clade Ib.

"The more infections you have, the greater the chance of a meaningful mutation"

This may have emerged even if vaccination efforts had been better, says Trudie Lang, also at the University of Oxford. "These things will pop up," she says.

But widespread vaccination in endemic countries would undoubtedly have helped control clade I, reducing the risk of it evolving. "There's no doubt that if we had more vaccines, there'd be less clade I," says Lang.

"It's always hard to say what 'would' happen, but mutations are a numbers game," says Jason Zucker at Columbia University in New York. "The more infections you have, the greater the chance of a meaningful mutation. If we were able to vaccinate more people in the DRC over the past one to two years, it's likely we would have seen less cases, less spread and, I suspect, not ended up with another public health emergency of international concern."

Vaccination is key

Along with more research and surveillance, adequate vaccination would have meant that the "chances are we wouldn't be here today", says Olliaro.

Mpox's fatality rate varies from 1 per cent to 10 per cent, with clade I being more severe than clade II. A lack of research makes it hard to say whether clade Ib differs to previous clade I subtypes in terms of severity and transmission, but it is thought to largely spread via sex and other forms of close contact, as we saw in the 2022 outbreak.

Despite the unknowns, it is clear that the outbreak has an increasing chance of spreading, both in the regions surrounding Central and West Africa and beyond, says Zucker. The declaration of a PHEIC is therefore considered by the experts to be a wise move. "Everybody's very pleased that [the PHEIC] was made because it mobilises the vaccine response and coordinated effort that we need," says Lang.

To prevent a third mpox PHEIC, the focus must pivot to endemic countries in Central and West Africa. They have been "facing this problem for years", says Olliaro. "After the end of the last PHEIC, the alarm went off but we went back to sleep." It's time to wake up, he says. ▮

Ukraine's nuclear question

Russia's attacks on Ukraine's nuclear power plants brought a dangerous new dimension to warfare. What should Ukraine do as it gains the chance to turn the tables, asks **Matthew Sparkes**

ALL four of Ukraine's operational nuclear power plants have been occupied or attacked by Russian forces since the start of the invasion in 2022. Now, as Ukrainian troops on the counteroffensive push deeper into Russian territory, roles could be reversed if Ukraine decides to take control of a Russian plant.

According to the Ukrainian government, its troops are now in control of the Russian town of Sudzha, almost 10 kilometres inside the border. This brings them within 70 kilometres of the Kursk Nuclear Power Plant (KNPP) – one of Russia's three biggest. The plant has two operational reactors, of a design similar to those used at Chernobyl in Ukraine, which date back to the 1960s. A further two more modern reactors are under construction, a type similar to those found at the Russian-occupied Zaporizhzhia Nuclear Power Plant (ZNPP) near the Ukrainian city of Enerhodar.

With Russia having gone to great lengths to seize Ukrainian reactors, will Ukraine relish the chance to turn the tables? Not likely, according to one Ukrainian scientist with a history of working at the Chernobyl site who says the elderly reactors weren't worth occupying. "We don't want such garbage," they say, speaking anonymously for fear of Russian reprisal.

But if its forces continue to make swift gains in the Kursk region, Ukraine may be compelled to decide the fate of the Russian plant. International Atomic Energy Agency director-general Rafael Mariano Grossi has already spoken out about the risk. "I would like to appeal to all sides to exercise maximum restraint in order to avoid a nuclear accident with the potential for serious radiological consequences," he said in a statement. "I am personally in contact with the relevant authorities of both countries and will continue to be [apprised] of the matter."

Ross Peel at King's College London says the Geneva Convention demands that countries take care around "installations containing dangerous forces" such as nuclear power plants, but that such agreements tend to be adhered to only as long as it is convenient.

Strategically, holding KNPP would be an unnecessary drain on Ukrainian military resources, says Peel. "The Russian army is quite slow moving, but when it arrives it's quite a force to be reckoned with," he says. "They don't want to be stuck there trying to hold this thing."

What about simply shutting it down to deprive Russia of energy? Laurence Williams at Bangor University, UK, says that KNPP, like many nuclear plants, must remain supplied with electricity to keep its electrical cooling systems running safely, even when shut down. Without cooling, the fuel in a powered-down plant could potentially heat up to such an extent that it ruptures the reactor and leaks radioactive material, says Williams. "Not dramatically, as in the case of Chernobyl, but possibly more akin to what happened at Fukushima," he says. Ultimately, cutting power to KNPP could risk Ukraine losing the moral high ground, says Peel.

Williams says the best course of action if Ukraine ended up in control of KNPP would be to leave things alone; allow skilled staff to stay and avoid disrupting the power grid. Indeed, a second Ukrainian scientist, still working near Chernobyl, says Ukraine probably doesn't have the expertise to run the Russian plant, given the way its design has evolved since the days of Chernobyl.

"The staff [in Ukraine] who know how to operate the [reactor] units are either retired or have already passed away," they say, speaking anonymously. "There were a lot of safety improvements in other reactor systems. All this means that Ukraine would not [be able to] safely operate the Kursk power plant."

A Ukrainian expert in nuclear safety who previously worked at Zaporizhzhia, and asked to remain anonymous, told *New Scientist* that holding the Kursk facility would bring additional challenges. "We [would] need other power structures, like the police and a lot of civilians," they say. Ultimately, taking a nuclear power plant requires occupying a lot of surrounding territory in a way that may be a low priority for the Ukrainian military. "I think they have other objectives."

Regardless of whether Ukraine moves on Kursk, Peel says the fact that nuclear power plants have become battlegrounds is causing waves in nuclear safety circles. Traditionally, plants have been designed to withstand criminal or terrorist attacks, he says, but now the world is having to contend with the idea that states could attack other states' plants.

"The more facilities there are in more countries, then the more risky this potentially becomes," says Peel. "I've seen people asking if this means that we should have no more nuclear power, because it's too risky."

Ultimately, it is in both Ukraine's and Russia's interests to avoid a nuclear incident, says Williams. "Why would they [Russia] want to spread radioactivity around their own area? If the wind was blowing, it would blow towards Moscow," he says. He hopes that Ukraine would recognise that it has a "moral responsibility to behave differently" to how Russia has with Ukrainian plants. ▮

70km

distance of Ukrainian forces from the Kursk power plant

The Kursk Nuclear Power Plant is one of Russia's biggest

ANATOLIY ZHDANOV/KOMMERSANT/SIPA USA/ALAMY

Psychology

Astrology shown to be no better than random guessing

Tom Leslie

YOU would think someone saw this coming. Astrology doesn't work, according to a detailed assessment of 152 astrologers that found their predictions were not only no better than random guessing, but also rarely agreed with each other.

There is no scientific basis for astrology, the belief that the motion of the planets and stars influences or predicts human behaviour, but it remains popular – one recent survey found that 27 per cent of US adults say they believe in the practice.

With previous scientific tests failing to dent astrology's appeal, Spencer Greenberg at US social enterprise Clearer Thinking came up with a new approach to help settle the question of its efficacy.

"We asked, can we design a study where if astrology works, it's very likely to come out in favour of astrology, and if it really doesn't work, it's likely that it's going to come out against astrology," says Greenberg.

To do this, he and his colleague André Ferretti asked six astrologers what they would want to know about a person's life and character to accurately identify their birth chart. These charts are a common tool in astrology, constructed using the observed positions of celestial bodies at the time of someone's birth, and claim to offer insights about that person's character or life.

Using this advice, the pair developed a questionnaire to gather this information and selected 12 respondents whose answers would be used as part of a test, which is available online. They then recruited 152 astrologers to match each completed questionnaire to a birth chart from a choice of five. Each astrologer did this for every respondent, for a maximum possible score of 12.

PAOLO GALLO MODENA/IMAGEBROKER/SHUTTERSTOCK

In astrology, your fate is supposed to be entwined with your star sign

When the results were in, the average number of correct answers was 2.49, equivalent to what would be achieved by randomly guessing (bit.ly/clearerthinkingstudy). "It's indistinguishable from random chance," says Greenberg.

Despite this, the astrologers had generally been confident in their answers, with 51 per cent thinking they had got six or more correct. "That is actually really key to our experiment," says Greenberg. "It shows that the people that participated largely believed that they could do this task."

What is more, the astrologers rarely agreed with each other's picks. Even the most experienced had agreement rates of less than 30 per cent. "This, to me, was really surprising," says Greenberg. "It suggests that astrology is maybe less standardised than you might think."

Richard Wiseman at the University of Hertfordshire, UK, says the work builds on a long history of similar research, but he doesn't think it is likely to affect the decision-making of people who seek astrological advice. "Generally, people engage with astrology because it addresses some kind of need," he says. "To change their mind, you would have to address what got them to that point to begin with."

27%
of US adults say they believe in astrology

Nicholas Campion, a historian of astrology at the University of Wales Trinity Saint David, UK, says that while this study is an effective test of birth chart predictions, that doesn't account for all forms of the practice. "There is no one single method of astrology," he says, "which suggests to me that it is very difficult to take an objective view of what astrology is or what it claims." ▮

Botany

Sunflowers work together to get enough light

Leah Crane

THE seemingly random motion of individual sunflowers in a crowded field actually minimises shade cover in such environments, ensuring that all of the plants get enough light to grow.

Scientists have been aware of this plant motion, known as circumnutation, for centuries, but its purpose has always been elusive. "In climbing plants, it's clear that it's a search process, searching for a new stick to twine on. But in other plants, it's not clear if it's a bug or a feature," says Yasmine Meroz at Tel Aviv University in Israel.

To find out more, Meroz and her colleagues grew sunflowers in a dense row and observed their motions over the course of 10 days, then created a computer model to quantify the movements. This showed that, as the plants twisted and turned, their growth gradually became optimised in such a way that all of them would get as much sunlight as possible.

"Adding this noise, this randomness in movement, seems counterintuitive because noise can lead to unwanted states," says team member Orit Peleg at the University of Colorado, Boulder. "But in this case, it's really important and can bring us closer to a more optimal configuration." The row of plants ends up in a zigzag pattern in which each sunflower gets enough light and the movement decreases (*Physical Review X*, doi.org/nc52).

Many plants go through motions similar to those of sunflowers, so this is a hint that they may all be able to optimise their growth to fit their surroundings, says Meroz. "These circumnutations might be a way of exploring the plants' environments and comparing signals in different places in order to identify the best growth strategy – which is pretty cool because we don't think of plants as navigating," she says. ▮

Astronomy

Star turns its planet egg-shaped

Earth-like exoplanet might be the most extreme example yet of a world contorted by gravity

Alex Wilkins

A DISTANT Earth-sized planet called TOI-6255b is orbiting so close to its parent star that gravity is stretching it to an extreme degree, turning it egg-shaped.

A handful of known exoplanets are extremely close to their parent stars, which exposes them to incredibly harsh conditions. These "ultra-short period" planets – they take less than a day to complete one loop around their stars – are blasted with radiation and often have surfaces composed entirely of lava.

Now, Fei Dai at the University of Hawai'i and his colleagues have discovered one of the most extreme examples of these objects. A year on TOI-6255b goes by in just under 6 hours, and the intense gravitational force from its star has warped the planet's shape to be 10 per cent longer in one direction. "The system is the most highly distorted that we know so far," says Dai.

The exoplanet is remarkably similar to Earth in some ways, with a radius just 1.08 times that of our planet and a mass 1.44 times as great. It is also likely to have a similar composition of iron and silicon (arXiv, doi.org/nc5z).

But the powerful radiation from the host star has heated one side of the planet to at least 1100°C (2012°F). Standing on its surface, you would look down at an ocean of molten rock beneath you and up at a star that appears 80 times larger than the sun does in Earth's sky. "You can imagine, if you're on this hellish planet, life wouldn't be very pleasant," says Dai.

"You can imagine, if you're on this hellish planet, life wouldn't be very pleasant"

Dai and his team discovered TOI-6255b using a relatively new planet-hunting telescope at the W. M. Keck Observatory in Hawaii. The Keck Planet Finder, which started looking for planets two years ago, can record the brightness and motion of stars with a much higher degree of precision than previous tools. The researchers used the instrument to infer the planet's properties, like its mass and radius, in great detail.

"Very often you don't get the wealth of data that the authors have gotten for a system like this," says Brian Jackson at Boise State University in Idaho. "Having all of that for this really gives us a deep insight into these kinds of systems that it's very hard to get."

We are probably observing the planet at the very end of its life, says Dai. Over the next few hundred million years, it will become even more stretched until it slowly disintegrates and is eventually eaten by its host star. While this is a relatively common occurrence – scientists recently estimated that one in 12 stars cannibalises a planet – it is much rarer to see the final stages of this process.

"The planet probably started out with much longer orbital periods, so we are catching it right at the end," says Dai.

The egg-shaped exoplanet also provides an opportunity to observe powerful magnetic fields in action. In our own solar system, planets are too far away to feel the effects of the sun's magnetic field, but TOI-6255b could be bathed in its star's magnetic field. "The planet probably sweeps through these loops of magnetised plasma because it's so close," says Jackson. While Dai and his team didn't look for these effects in their study, they should be able to check for them in future work, says Jackson. ▮

Zoology

Spiders use firefly light to lure more prey into their web

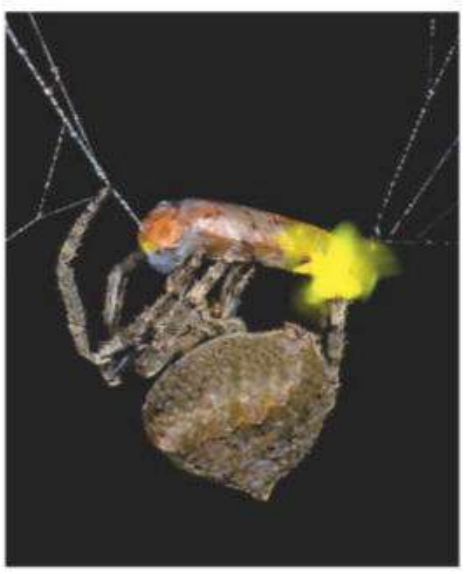
ARACHNIDS have a bright way of arranging home food deliveries. Once orb-weaver spiders ensnare male fireflies in their webs, they turn the doomed insects into bait, using their flashing light to attract other fireflies to be their next meal.

Xinhua Fu at Huazhong Agricultural University in China noticed that male fireflies (*Abscondita terminalis*), but not females, often got stuck in the web of orb-weaver spiders (*Araneus ventricosus*), and he wondered if the males were being lured into a trap.

Males and females of this firefly species both use flashing signals in courtship, and the females' light attracts males to their location.

To investigate the phenomenon, Fu and his colleagues ran experiments on 161 webs, some with and some without spiders, in a stretch of farmland in Hubei Province, China. The researchers placed a male firefly – some of which had their bright abdomens blacked out with ink – in each web. They found that webs with both a spider and a freely flashing firefly attracted more male fireflies than webs with no spiders present or with non-flashing fireflies.

Also, the male fireflies entangled in a spider-occupied web had an unusual flash signal. It looked more like that of females, with one pulse instead of two. But fireflies in an empty web flashed normally (*Current Biology*, DOI: 10.1016/j.cub.2024.07.011).



XINHUA FU

An orb-weaver spider wrapping up a glowing firefly

This suggests that the spiders are manipulating the male fireflies' signals to mimic those of females, luring in other males searching for mates, says team member Daiqin Li at Hubei University. How the spider alters the signals of its immobilised prey is unknown, but the team has some ideas. "The spider's venom or the bite itself may lead to changes in the ensnared males' flashing pattern," says Li.

He is interested in seeing if other firefly-eating spiders use a similar tactic. Animals may use captured prey as lures by capitalising on other signals, he says, such as sounds or the release of pheromones.

The work demonstrates again that spiders aren't passive foragers, says Mariella Herberstein at Macquarie University in Australia. "We are discovering more and more cases of highly complex and selective feeding techniques." ▮

Jake Buehler

Analysis Artificial intelligence

Why the T in ChatGPT is AI's biggest breakthrough – and greatest risk

Tech firms hope that feeding ever more data to their artificial intelligence models will lead to human-level skills. Behind this hope is the "transformer", but what happens if it fails to deliver, asks **Alex Wilkins**

WHEN ChatGPT first took the world by storm in 2022, its capabilities were so impressive that people happily looked past its awkward name. Yet hidden within those initials lies a key breakthrough responsible for sending artificial intelligence rocketing these past few years – and potentially a limitation that could see it crashing back to Earth.

GPT stands for generative pre-trained transformer, and it is the last word that matters most.

"It's not like you can just sit down at a whiteboard and think up a new way to do this and it works"

The term was coined in a 2017 paper by a team at Google, which introduced a concept called self-attention. This means that when a model is given a string of words, it doesn't consider each one by itself, but instead makes links between the words it has already been fed, "transforming" the whole input into a new output.

That design yielded huge success when given enough computer power and data, leading to the surprising jump in apparent reasoning and language capabilities behind today's AI tools. What's more, using ever greater levels of computing power and data seems to continually improve a transformer's performance.

This "scaling law" is why AI companies have predicted that their models will get better and better, with OpenAI claiming that its upcoming GPT-5 model will have the reasoning capabilities of a PhD student, approaching the field's grand goal of achieving artificial general intelligence (AGI), a machine capable of anything a human can do.

Outside observers are more sceptical, however. OpenAI has seen a number of high-profile departures this month, with prominent AI researcher Gary Marcus posting on X that people leaving the firm would be "inconceivable if AGI or even just major profitability were close".

More fundamentally, some researchers question whether these all-important scaling laws can continue unimpeded, especially as most of the available data to train the models on, which is largely scraped from the internet, has already been gathered. "You need more knowledge, you need more text," says Sepp Hochreiter at Johannes Kepler University Linz in Austria. There is some hope that using AI to generate "synthetic" data might push through this barrier, but others are sceptical.

Even if transformers continue to follow these scaling laws, there could still be fundamental problems with their design. One is that they lack an internal memory, says Hochreiter, which we know is central to the way that human intelligence works.

Transformers must also repeatedly look back at data they have already seen. Processing and generating long text sequences can therefore require enormous computational resources as the AI scans back and forth. This isn't as much of a problem when working with short emails or simple questions, but it makes transformers ill-suited for working with longer text sequences, like books or large data sets, says Yoon Kim at the Massachusetts Institute of Technology. "Transformers are just fundamentally inefficient and are ill-equipped for these types of applications."

SEONGJOON CHO/BLOOMBERG VIA GETTY IMAGES

Sam Altman's OpenAI aims to build a machine capable of human-level reasoning

DAVID PAUL MORRIS/BLOOMBERG VIA GETTY IMAGES

Google researchers coined a new use of the word "transformer" in 2017

Researchers hope to solve these problems with alternative neural network architectures, such as a model developed by Hochreiter and his colleagues called extended long short-term memory (x-LSTM). Its predecessor, just known as LSTM, was the de facto AI language architecture before transformers took over, but Hochreiter says the new version, which has many more artificial neurons and a redesigned memory, produces comparable results to transformers while being much more efficient and able to remember past states.

But these models, while offering advantages to the transformer, aren't radical evolutions, says Kim. "These aren't very different models from one another. If you go high-level enough, they're essentially the same model."

A deeper problem with both transformers and their alternatives is whether they are "Turing complete", which means they are able to run any algorithm or compute anything that any other computer can. This might seem like a technical point, says Razvan Pascanu at Google DeepMind, but if future AI systems are to be as reliable and capable as we want them to be, then demonstrating that they are Turing complete is important.

Take a simple problem: adding two numbers. Because transformers work by extrapolating from their training data, they are good at adding together numbers they have seen many times, but can produce inaccurate results for numbers not found in their training data.

While transformer arithmetic is improving as models scale up,

it still isn't clear if they have the capability to do addition in a Turing-complete way, as any other computer would. "When we build these systems, we're trying to make them approximate some function we care about, and usually this is what's going on," says Pascanu. "But for certain things, like addition, you might care about representing the addition algorithm exactly – you don't care about approximating addition."

So, what is the solution? Finding an AI architecture that can perform as well as the transformer, while also solving the current problems with efficiency and memory, is no easy task. "It's really hard to find good neural network architectures that work," says Jonathan Frankle at AI company Databricks. "It's not like you can just sit down at a whiteboard and think up a new way to do this and it works. There are a lot of grad students and people who have thrown a lot of time and energy into failed efforts to just improve the transformer, let alone to come up with something whole-cloth new and different."

This means that if the transformer fails to live up to the heady promises of AI firms or if the scaling laws don't follow their observed trajectory, it isn't obvious where an alternative might come from. The commercial pressures at big AI companies leave little room for experimentation, says Frankle, and with transformers so entrenched in current AI systems, it is unclear if they can change course now.

"Even if you do come out with something that's very interesting and exciting, the standard of proof for you to convince someone to switch over to that, to take the risk on their billion-dollar training run to use your thing, is exceedingly high," he says. ▮

Health

Video games are actually good for mental health

Tom Leslie

PLAYING video games really does seem to boost your well-being, despite the pastime often being maligned.

"I guess if you enjoy your hobby, you're going to find a good impact to your well-being," says Hiroyuki Egami at Nihon University in Japan.

In 2019, the World Health Organization added "gaming disorder" to its International Classification of Diseases. But research into the effects of playing video games has shown mixed results, with many studies being unable to prove cause and effect when it comes to mental health outcomes.

Studies that aim to do so usually take place in a lab, yet these are "far removed from what it's actually like to play video games", says Peter Etchells at Bath Spa University in the UK.

But between 2020 and 2022, Egami and his colleagues hit on a rare chance to investigate any causal effect of video games on a person's well-being in the real world. Consoles were in short supply during this time, so parts of Japan introduced lotteries, where people could enter a ballot to have a chance of getting a PlayStation 5 or a Nintendo Switch gaming console.

The researchers surveyed 8192 people, aged between 10 and 69, who had entered one of these lotteries. The respondents answered questions related to their gaming habits and levels of psychological distress, an indicator of mental well-being.

Egami and his colleagues found that those who won the lotteries had slightly better mental well-being scores than those who didn't, although this plateaued after about 3 hours per day of total playing time.

They also used a machine-learning model to show that the effect varied depending on the console and the demographics of the owner. For example, younger people with a Nintendo Switch saw a greater benefit than older counterparts, and people without children had better well-being scores from having a PlayStation 5 than parents did (*Nature Human Behaviour*, doi.org/ndd3).

If you enjoy video games, playing them may be nothing to worry about

10'000 HOURS/GETTY IMAGES

"It highlights that, if we care about understanding how video games impact us, we need to be nuanced and specific about what it is that we're measuring and how," says Etchells.

However, he says, doing the research during the covid-19 pandemic may have affected people's habits and well-being. ▮

See page 14 for an analysis on young people's mental health

Space

Lightning can cause turmoil far into space

ENERGY from lightning can reach the top layers of the atmosphere, where it could present a threat to astronauts and satellites.

When lightning occurs, the energy it carries sometimes gives rise to electromagnetic waves called whistlers, so named because they can be converted to sound signals. These whistlers were thought to remain trapped relatively close to Earth's surface, below about 1000 kilometres.

Now, Vikas Sonwalkar and Amani Reddy at the University of Alaska Fairbanks have discovered that some whistlers can bounce off a layer of the atmosphere called the ionosphere, which is filled with charged particles.

This enables the waves, and the energy they carry, to get up to 20,000 kilometres above the planet's surface. That means they can reach the magnetosphere, the region of space dominated by Earth's magnetic field.

Sonwalkar and Reddy found evidence of these reflected whistlers in data from the Van Allen Probes that measured the magnetosphere between 2012 and 2019. They also saw signs of them in studies from as early as the 1960s (*Science Advances*, doi.org/ndd6).

Lightning could be contributing twice as much energy to this area of space as previous estimates indicated, says the team. This would charge and accelerate nearby particles, producing electromagnetic radiation that can damage satellites and harm the health of astronauts. ▮

Karmela Padavic-Callaghan

Analysis Psychiatry

Is young people's mental health really worse today than it was decades ago?

Smartphones, covid-19, social media and climate change may all be affecting the mental health of children and young adults, reports **Carissa Wong**

YOUNG people's mental health "has entered a dangerous phase" and "now might be our last chance to act", scientists have written in the journal *The Lancet Psychiatry*. They argue that accumulating evidence indicates a steady decline in the mental health of people aged 12 to 25 over the past two decades, with covid-19 causing a recent major plummet (doi.org/gt6z46).

Aside from the pandemic, some also point the finger at climate change and smartphones, arguing that these affect younger people more than their older counterparts, or even didn't exist to the same extent when the latter were children.

Another argument asks whether a rise in youth mental health issues just comes down to increased awareness of these problems and a reduced stigma around them, which may prompt young people to answer related surveys more honestly and seek out diagnoses.

Whatever the causes, statistics signal that a change has occurred in recent years. In England, for example, surveys suggest that 20 per cent of children aged 8 to 16 had a probable mental health condition in 2023, while just under 13 per cent of 5 to 19-year-olds had at least one mental health condition in 2017. Statistics from other countries, including the US and Australia, tell a similar story, with poor mental health also seeming to increasingly affect young adults.

One thing that didn't widely exist two decades ago was smartphones. Although often blamed for rising rates of depression and anxiety among young people, the data is generally inconclusive. But recently, a randomised controlled trial, the best kind of scientific evidence, of 181 children and adolescents found that giving up smartphones and reducing other forms of screen time to a maximum of 3 hours a week for 14 days was associated with improved psychological symptoms.

It could be that the problem is less to do with smartphones themselves than what young people are using them for. Studies have linked social media, which is often accessed via these devices, to online bullying, self-harm behaviour and suicide ideation. However, "it's really important that we don't just put it all in one bucket and say social media is bad", says Emily Simonoff at King's College London.

Sites like Facebook and Instagram can help young people connect with others during a phase of life where a sense of social belonging is especially important, says Karen Mansfield at the University of Oxford.

Another factor is that people who were children two decades ago didn't have to contend with the covid-19 lockdowns at a young age.

While these affected all of society, children and teenagers can't shape their environments like many adults can, so may have felt particularly out of control, says Simonoff. It also left many young people feeling unsupported and lonely, she says.

A surge in youth mental health problems at this time has been linked to the shift to remote learning, but for some, returning to schools may have actually worsened their mental health. A recent study found that going back to school was associated with increased psychiatric emergency department visits among children and teens in Italy.

"Stresses – like the pandemic, like climate change – they're compounding each other"

"A lot of children, for example, who were very anxious at school, were actually quite happy to be at home, to learn online, to have their parents supporting them," says Mansfield.

Another global crisis widely thought to harm youth mental health is climate change. Beyond its physical effects, such as heat-related deaths and extreme weather events, its mental health consequences have been dubbed eco-anxiety, which seems to disproportionately affect young people.

Researchers at Stanford University in California recently found that among people aged 18 and older in the state, the younger ones were more likely to experience mental health symptoms related to climate change.

Global warming is especially concerning for young people, who have more years ahead of them than older people, says Emma Lawrance at Imperial College London. They also feel frustrated that they have been left with a crisis they didn't create, she says. "There is a sense of betrayal and understandable anger that disrupts their sense of a positive vision of the future."

Beyond existential worries, exposure to extreme heat in early childhood has been linked to brain changes that may harm mental health, says Lawrance.

All this hints that the decline in youth mental health isn't just the result of improved awareness. "In terms of recent history, I'd say it's really getting worse," says Mansfield.

Ultimately, it is unlikely that any single factor is to blame. "Uncertainties and stresses – like the pandemic, like climate change – they're compounding each other," says Lawrance.

When it comes to rectifying some of these issues, experts want youth mental health to be a catalyst for action. "Young people are picking up on things that are happening in the world, and the fact they're not OK is a reflection of these trends in the world that are not OK," says Lawrance. "It's the canary in the coal mine." ▮

The worsening of global warming has been linked to a rise in eco-anxiety

SHEILA FITZGERALD/ALAMY

Need a listening ear? UK Samaritans: 116123 (Samaritans.org); US 988 Suicide & Crisis Lifeline: 988 (988lifeline.org). Visit bit.ly/SuicideHelplines for other countries

Zoology

Cockroaches shrug off consumer insecticides

Madeleine Cuff

PEOPLE buying insecticide sprays to battle cockroaches are wasting their money because the insects have grown resistant to a key ingredient.

Johnalyn Gordon at the University of Florida and her colleagues have shown that while consumer sprays that contain pyrethroid insecticides kill lab-sourced German cockroaches (*Blattella germanica*), they are ineffective against insects collected from real-world infestations. This species is common throughout the world, and the one most likely to infest buildings.

The products are designed to be sprayed on to surfaces, killing the insects when they walk over the coating. But in the team's tests, coated surfaces killed fewer than 20 per cent of collected cockroaches after exposure for 20 minutes. "Even directly spraying them in an enclosed container with these products, we weren't getting 100 per cent mortality," says Gordon.

When the cockroaches were forced to remain on the treated surfaces, most of the products took between 8 and 24 hours to kill (*Journal of Economic Entomology*, doi.org/nc5w). Previous research has shown that these insects avoid lingering on surfaces treated with pyrethroids, though.

Pest-control products sold in the US must prove a 90 per cent efficacy rate, but there is no general requirement for testing on field-collected insects. This should change, says Gordon.

In the meantime, cockroach baits are probably the most effective consumer product for controlling infestations, she says, and to also minimise human exposure to pesticides. Other in-home strategies, such as removing food and water sources used by the insects and clearing clutter, can also help. Professional pest control, which relies on pesticides beyond pyrethroids, is also recommended. ▮

Solar system

Strange meteorites traced to their source craters on Mars

Leah Crane

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

Impact crater on Mars, with darker material exposed beneath the reddish dust

SIX meteorites that crashed down on Earth have been traced back to the craters they were ejected from on Mars millions of years ago. Finding the sources of these alien rocks will allow us to place them in context, yielding insights about the history of the Red Planet.

"Being able to identify the impact launch sites for any Martian meteorites has been a challenging goal for a long time," says Hap McSween at the University of Tennessee, Knoxville, who wasn't involved in this work. "There have been numerous published attempts before, but none have been very convincing until now."

When a rock smashes into Mars or another planet, it causes a spray of debris, some of which can float away through space and eventually hit Earth as a meteorite. Anthony Lagain at Curtin University in Australia and his colleagues have used a model that matches what we know about the ages of the millions of Martian craters and of the six meteorites that were chipped off the planet's surface.

"On Mars, you've got about 80,000 craters larger than 3 kilometres, so about 80,000 craters that might be the source of these meteorites," says Lagain. The researchers' model narrowed this down to around 20 possible sources. Then, they studied the structure of the meteorites to find out how much force they had been suddenly subjected to when blasted into space, feeding that into another model of the craters themselves.

This led them to where these rocks were originally buried and how deep they probably were before the impacts that sent them to Earth (*Science Advances*, doi.org/ndbk).

The meteorites are all igneous rocks, meaning they are pieces of solidified lava. Pete Mouginis-Mark at the University of Hawai'i at Mānoa says that while there are questions about whether the properties of the lava flows in these craters completely match the meteorites, if these craters are the sources of the rocks, we can learn a lot about Martian volcanic activity from them.

In particular, two of the meteorites that seem to have come from the same crater imply that the area was volcanically active for longer than was thought likely. "We will have to rethink what we believe to be the internal 'plumbing system' of volcanoes on Mars and how they can stay molten for these extended periods of time," says Mouginis-Mark.

There are only about 200 known Martian meteorites on Earth and they are the only Mars rocks that researchers can examine in detail. NASA's planned mission to bring back samples directly from Mars is facing issues that may lead to its delay, so these rocks might be our only chance to study Martian material in state-of-the-art laboratories for a long time.

"Here, we've got six Martian meteorites coming from five places, so it's like five sample return missions that you get for free," says Lagain. Studying these samples further could not only teach us about the evolution of Mars, but also help guide future exploration to the most scientifically interesting spots on the surface. ▮

Water inside Mars

A study using data from NASA's InSight lander has revealed a possible reservoir of water near Mars's equator. InSight found the water buried 11.5 to 20 kilometres underground by searching for marsquakes and measuring how fast those seismic waves travelled. This revealed that the rocks the quakes were propagating through seemed to be saturated with water (*PNAS*, doi.org/nc6z).

Archaeology

Stonehenge's Scottish connection

We have finally identified the nearest source of the altar stone at the centre of Stonehenge – and it probably came all the way from Scotland, says **Michael Le Page**

THE 6-tonne altar stone at the heart of Stonehenge was almost certainly brought there from north-east Scotland, much further than any other stone in the megalithic structure.

"All of us were stunned. We couldn't believe it," says geologist Anthony Clarke at Curtin University in Perth, Australia.

How the altar stone was transported all the way from Scotland to the south of England isn't known, but it is most likely to have been brought by sea, he says. There is evidence that people at this time were making sea journeys, says Clarke.

Stonehenge is thought to have been built over about 1500 years, starting around 5100 years ago. It consists of an outer circle of large stones weighing around 25 tonnes each, known as sarsens, and an inner ring and altar made of smaller stones generally of around 3 tonnes, known as bluestones. The term bluestone just means any rock that isn't a sarsen – the bluestones are made of various kinds of rock.

"The thing that's unique about Stonehenge is the distance that stones have been transported," says team member Richard Bevins at Aberystwyth University, UK. Most stone circles are made from rocks found within a kilometre of the site, says Bevins.

The source of the sarsens, however, has been traced to the West Woods of Wiltshire, around 25 kilometres from the site. And Bevins's team has shown that almost all the bluestones come from the Preseli hills in Wales, about 280 kilometres away. One idea is that they were part of an even older Welsh stone monument that was moved.

The altar stone at Stonehenge is different to the other bluestones. "By the end of 2021, we'd come to the conclusion that the altar stone didn't match any of the geology that we knew in Wales," says team member Nick Pearce, also at Aberystwyth University.

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PROFESSOR NICK PEARCE, ABERYSTWYTH UNIVERSITY

Most of the stones that make up Stonehenge (above) come from relatively nearby Wiltshire and Wales, but not the buried altar stone (below)

750km

lie between the altar stone and its closest matching source rocks

This 5-metre-long stone is embedded in the ground with only one surface showing and is partly covered by two other stones. It is thought to have been put in place about 4500 years ago.

Now, Clarke's team has taken sophisticated equipment usually used in the mining industry and analysed samples of the altar stone. It is a sandstone, which means it is made of eroded grains of rock that piled up at the bottom of an ocean and eventually stuck together to form a new rock. The age of each grain varies depending on when the rock it eroded from first formed, so different sandstones have a distinctive mix of grains of different ages.

The team analysed individual crystals of the minerals zircon, apatite and rutile within samples of the stone. These minerals contain uranium, which very slowly decays to lead, allowing them to be dated from the ratio of uranium to lead. For instance, the zircon in the stone is between 500 million and 3 billion years old.

The pattern of ages shows with greater than 95 per cent certainty that the altar stone is Old Red Sandstone from the Orcadian basin in north-east Scotland, says team member Chris Kirkland at Curtin University. This basin was once a massive water body called Lake Orcadie. The nearest matching Old Red Sandstone to Stonehenge is 750 kilometres away near Inverness, and the furthest is in the Shetland Islands up to 1000 kilometres away – hence why the team thinks the altar stone was probably transported by sea (*Nature*, doi.org/gt66t6).

Glaciers can carry boulders long distances, but the evidence is that during the last glacial period, the flow of ice in the Orcadian region was northwards rather than southwards, says Kirkland.

So why was the altar stone brought such a long distance? "That is the great unanswerable question," says Clarke. "All we know is it's a 6-tonne piece of rock that's come from 750 kilometres away. That, by itself, tells us an awful lot about the Neolithic society and its connectivity."

"What they've done is pretty rigorous," says David Nash at the University of Brighton, UK, whose team identified the precise source of the sarsens in Wiltshire. "It's a really sound piece of work."

Pinning down the source of the altar stone more precisely will be difficult because the Orcadian basin extends over a vast area and is up to 8 kilometres deep, says Nash. "That's a big, big job, because there's an awful lot of Old Red Sandstone in northern Scotland."

With the sarsens, by contrast, there were fewer potential sources, so locating the exact one was easier, he says. ▮

Consciousness

1 in 5 people in a coma may actually be aware of their surroundings

Helen Thomson

MORE people in comas than we thought may be "locked in", meaning they are aware of their surroundings but unable to communicate. And some of those with severe brain damage can carry out complex mental tasks when instructed, despite not being able to move or speak.

It was easier to discount the phenomenon "when it was thought to be a rare occurrence", says Nicholas Schiff at Weill Cornell Medical College in New York. But now, given the new findings, "no one can ignore it".

People with so-called disorders of consciousness are either in a coma or a vegetative state, where they show no awareness of their environment, or a minimally conscious state, where they show occasional signs of arousal, such as opening their eyes, but minimal awareness. In 2019, researchers discovered that 1 in 10 of these individuals may be locked in.

To find out if doctors were missing people in this state, Schiff and his colleagues carried out behavioural and brain imaging tests on 353 people with severe brain damage over eight years at six international centres.

The participants were asked to think about performing an activity – such as playing tennis, swimming or clenching their fist – for 15 to 30 seconds, before pausing, and thinking about the activity again. This was repeated seven times over 5 minutes.

In people without disorders of consciousness, these thoughts produce distinct brain activity that can be identified using MRI scans or electroencephalograms. Among the 353 people with brain damage, 241 showed no outward response to verbal commands. But of these, 25 per cent showed brain activity that matched that of volunteers without brain damage. For those in a coma or a vegetative state specifically, the figure was 20 per cent (*NEJM*, doi.org/nc3w).

"These are very demanding tasks – try thinking about swimming on and off for 5 minutes," says Schiff. "We don't know exactly what they are experiencing, but the fact that they can do this means there's a very good chance that they have awareness."

"For many people, the prospect of being kept alive in a non-conscious state is at best futile"

Estimates suggest that there are between 300,000 and 400,000 people with a prolonged disorder of consciousness worldwide, says Schiff, meaning up to 100,000 could have hidden awareness.

This study is of immense importance, says Raanan Gillon at Imperial College London. For many people, the prospect of being kept alive in a non-conscious state is at best futile and at worst abhorrent, he says. "If, however, there is a significant probability that the lack of consciousness is only apparent, as these studies suggest may be the case, it can be anticipated that more people would wish to be kept alive and be consulted about their wishes before decisions are taken to discontinue life-prolonging treatment."

Several ethical issues, including respect for people's human rights, "require re-evaluation in light of these studies", he says.

Brain-computer interfaces that can transform brain activity associated with attempted speech into text on a screen could provide a way of giving people with consciousness disorders two-way communication, says Schiff. ▮

Zoology

Wild crocodiles trained to stop eating deadly toads

A DOSE of food poisoning is helping to teach freshwater crocodiles in Australia how to avoid eating lethally toxic cane toads.

Cane toads (*Rhinella marina*) were introduced to Australia in the 1930s to control agricultural pests, but have themselves wreaked havoc with native wildlife as they have spread across the continent.

Native predators are naive to the threat posed by the toads, which secrete a compound called bufotoxin. Eating the toads is almost always deadly, says Georgia Ward-Fear at Macquarie University, Australia. "There is no opportunity to have a non-fatal encounter and learn a lesson not to eat them," she says. Populations of freshwater crocodiles (*Crocodylus johnstoni*) in some areas of northern Australia collapsed by more than 70 per cent as the first waves of the toads swept through.

SHUTTERSTOCK/AEONWAVE

Freshwater crocodiles (*Crocodylus johnstoni*) normally die after eating a cane toad

To attempt to help, Ward-Fear and her colleagues monitored four crocodile populations in the Fitzroy Valley region of Western Australia as the toads approached in September 2021. They set nearly 2400 baits – removing the toxin from toad carcasses and infusing them with lithium chloride, which is known to induce non-fatal nausea in reptiles. The team also set unbaited chicken necks as a control.

Initially, nearly all the baited toads and unbaited chicken necks were eaten, but within five days, as food poisoning symptoms spread, the predators began to wise up and stopped eating the toads, while continuing to munch on the chicken (*Proceedings of the Royal Society B*, doi.org/nc3v).

The crocodiles also seem to have learned to avoid live cane toads. In areas where the toads had recently arrived before the training, crocodile mortality fell by 95 per cent. ▮

James Woodford

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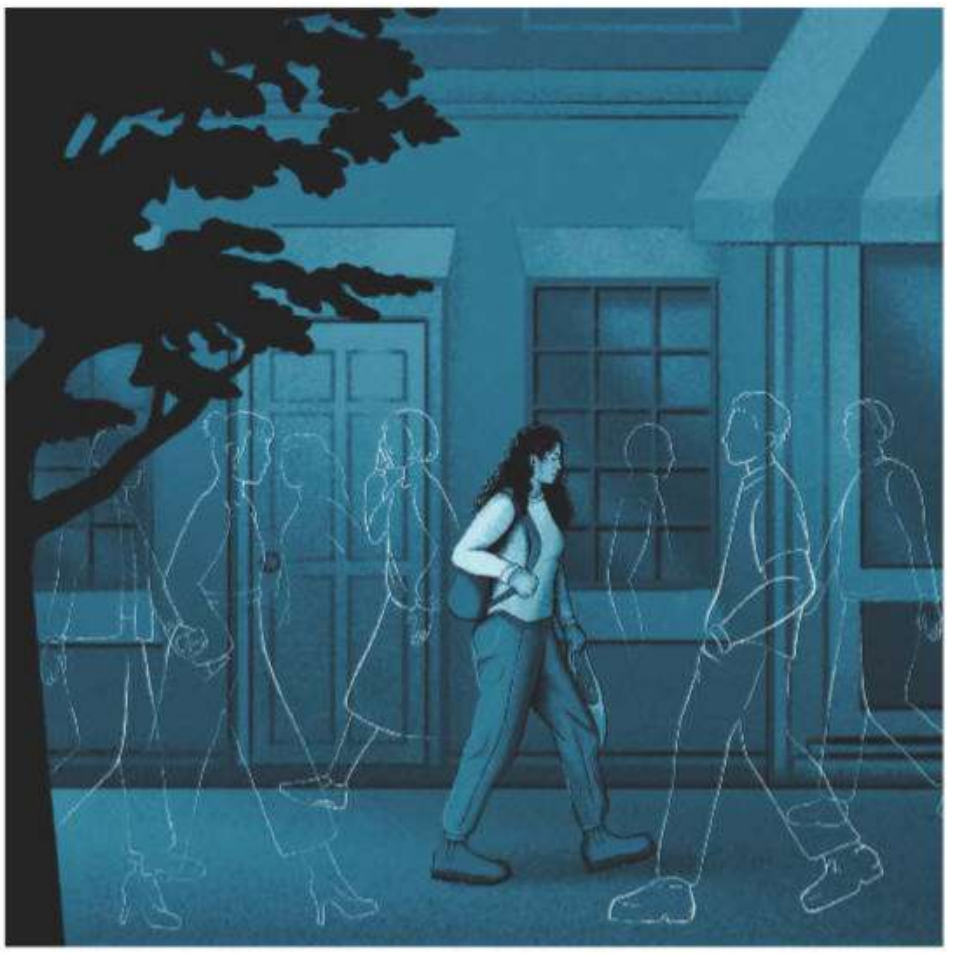
Comment

That shrinking feeling

Our ability to exert conscious control over our family sizes is unique – and can be transformational, says **Christopher Wills**



ELAINE KNOX

IN 1968, husband and wife biologists Paul and Anne Ehrlich published *The Population Bomb*, a terrifying look at coming ecology-driven disasters. Our population growth, they said, had to be slowed or reversed, or else catastrophe would ensue.

The world's population has more than doubled since that time, to over 8 billion people, and the disasters are still looming. But now, a new factor has entered the picture, one that has never been seen before in the entire history of life on our planet.

Italy's population has shrunk by around a million since 2014. Japan's has fallen by about 5 million since 2010. No species of organism has ever willingly shrunk its population before. Biologically, it is utterly paradoxical.

The answer to this seeming contradiction involves both our cultures and our biology. We have distinctly clever brains, shaped by the unique evolutionary path that we have taken. We are now the only species that has ever gained the ability to exert conscious control over our family sizes.

All others, as Charles Darwin was the first to realise, are locked in the iron grip of the imperative to out-reproduce their competitors. Indeed, if an ability to be hesitant about the consequences of unchecked reproduction were to evolve in any other organism, that species would immediately be driven to extinction by its gleeful predators and parasites.

Our brains, aided by the knowledge that we have accumulated and the cultures we have created, have shaped our recent history in a way closed to all other species. In the fraught world of my childhood, we kids were feasted on by a roistering crowd of dangerous bacteria and viruses. My little friends and I got mumps, measles, chickenpox and diphtheria, though we managed to dodge polio. Now, many children live in a comparatively safer world. It is shaped by our growing ability to define, like no other species before us, our place on the planet – and by our capacity to understand the consequences of what we have done.

Human societies are expressing these unique abilities to different degrees. Nonetheless, some have changed at a rate never achieved by any other species. During my own lifetime, many societies' attitudes towards large families have shifted from unrestrained adoration to awkward discomfort.

Population decreases are freaking out traditional economists, who trumpet the supposedly terrifying fiscal consequence of shrinking pools of workers, and populations of retirees that are exploding. But another fascinating feature of this emerging story is that the countries that might seem most likely to be damaged by population shrinkage are the very ones that are best equipped to overcome its effects.

When our populations shrink, as is happening most dramatically in Japan, we are given some much-needed breathing room. This lets us fix any economic threats by small tweaks of the tax code to take care of the growing ranks of older people. There is plenty of room for such changes in both Japan and Italy. In part because their rate of growth has slowed, both countries are near the world's top in median per capita wealth. This means that both nations are rich, and this bounty is quite equitably distributed. That will help these societies, not to decline into some state of grimly inevitable genteel poverty, but to continue and to accelerate positive societal trends.

For the first time in Earth's history, one of its species has evolved the capacity to move beyond the raw imperatives of evolution. And this ability, which might once have led to our extinction, is opening up new and wonderful ways for us to come into balance with our planet. ▮

Christopher Wills is a biologist and author of *Why Ecosystems Matter*

Field notes from space-time

Look to the stars

After 25 years in orbit, the Chandra space telescope is under threat. We need to protect this monument to human ingenuity, argues **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading
A friend gave me a copy of Andreea Kindryd's From Slavery to the Stars: A personal journey, *and it's beautiful.*

What I'm watching
I've been watching classic episodes of Star Trek: The Next Generation *like "Remember Me".*

What I'm working on
I'm developing a new course that will prepare students to understand science in social context.

This column appears monthly. Up next week: Graham Lawton

ON 23 July 1999, just months before I started university, NASA's space shuttle Columbia launched with precious cargo on board. Not only was it carrying the first crew to be led by a woman, Eileen Collins, but its primary goal was to launch a new flagship space telescope, the Chandra X-ray Observatory. Chandra was the heaviest payload that NASA's space shuttles ever carried, and it turned out to be one of the last two completed missions by Columbia before it tragically exploded after launch on 1 February 2003.

Chandra was the first, and so far only, NASA mission named for a person of colour, the late theoretical astrophysicist and Nobel laureate Subrahmanyan Chandrasekhar, known to his friends and family as Chandra. Chandrasekhar, whose family name means "moon crown", made many significant contributions to astrophysics. His most important was figuring out the Chandrasekhar limit, the maximum mass a white dwarf stellar remnant can be before it collapses and forms a black hole.

It is appropriate to name an X-ray telescope mission after a scientist who spent his life thinking about the physics of black holes, because X-ray telescopes play a key role in black hole research. X-rays are high-energy light waves. This means they are produced in extremely energetic environments like the regions around black holes, where the strong gravitational pull due to space-time's extreme distortion causes particles to accelerate to very high speeds. In other words, we see a whole other universe when we look at it through the lens of X-ray astronomy rather than the visible wavelengths of more traditional telescopes.

Importantly, X-ray astronomy can't be done from Earth's surface because our atmosphere blocks X-rays. That is good for human health, but not so great for astronomers. Thus, Chandra serves as a reminder of how important it is to keep low Earth orbit free of debris: we need to be able to safely launch space telescopes that do work we simply can't manage from the ground.

I feel that I have grown up with Chandra, and not just because attending university at Chandra headquarters, now known as the Center for Astrophysics (CfA) in Massachusetts, meant being

"Thanks to Chandra, we have discovered neutron stars, and our knowledge of black holes has blossomed"

mistakenly called "Chandra" a lot. One of my undergraduate lab projects was calibrating the light-collecting part of a back-up camera for Chandra. The following year, I wrote my undergraduate thesis under the supervision of X-ray astronomy expert Martin Elvis. My research focused on winds of particles that fly out of galaxies that are home to supermassive black holes. I used Chandra data to analyse what structure these galaxies might take. I know for a fact that Martin's letter secured my admission into at least one PhD programme. In other words, without Chandra, my career might never have launched.

I am one of thousands of scientists across physics and astronomy who can tell a similar story about how Chandra data has provided the foundation for their early career steps, or who have dedicated their lives to exploring cosmic mysteries using Chandra. Laura Lopez at The Ohio State University has long used Chandra to research supernovae. Daniel Castro, now a staff scientist at the CfA, does the same. The three of us were all postdoctoral researchers together at the Massachusetts Institute of Technology, part of a generation raised on the power of the Chandra X-ray Observatory.

Today, after 25 years in orbit, Chandra is under threat – not from space debris or the realities of ageing equipment, but instead from political winds. US President Joe Biden's political appointees at the head of NASA recently sought to wind down the project, but the scientific community has worked with Congress to save the mission. But things won't be the same. The compromise, yet to be signed into law, involves significantly defunding and limiting the scientific reach of Chandra. There is no scientific argument for doing this, especially against the recommendations of professional advisors. Even so, NASA has cut grants that were already promised to scientists, leaving PhD students and postdoctoral researchers without expected funding that covers the salaries they live on.

Chandra deserves better, and so does its global audience. Thanks to Chandra, we have discovered new neutron stars and learned about their interiors. Our knowledge of black holes has blossomed. We better understand the stellar life cycle and the history of our galaxy. We have been able to situate the Milky Way in context, studying galaxy clusters and learning about how dark matter is distributed in them. There is still time to save Chandra, which is a monument to human ingenuity. The fact it is still going strong after 25 years should be celebrated, and honoured by continuing the mission. ▮

‘Brightling’

Despite its 10.95mm height, the Trident C60 Pro 300 ‘Lumiére’ leaps from your wrist. (Just like it jumped off this page.) Its brightness results from proudly protruding indices and the logo they encircle. Featuring facets finely machined to tolerances of 0.03mm, these mini-monoliths are super-legible in daylight. But it’s the Globolight®, the unique luminous ceramic from which they’re hewn, that produces their astounding, super-brilliance at night. And inspired this timepiece’s name. The light show doesn’t end there. Carved from titanium, the 41mm case incorporates a second sapphire crystal displaying its super-accurate movement. But it’s not the back of this beautiful tool watch you’re buying into. Is it?

Do your research

Christopher Ward

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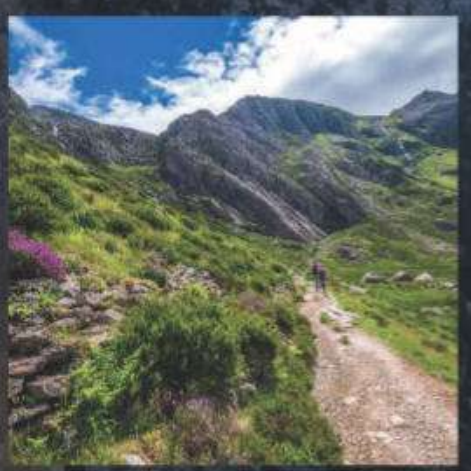

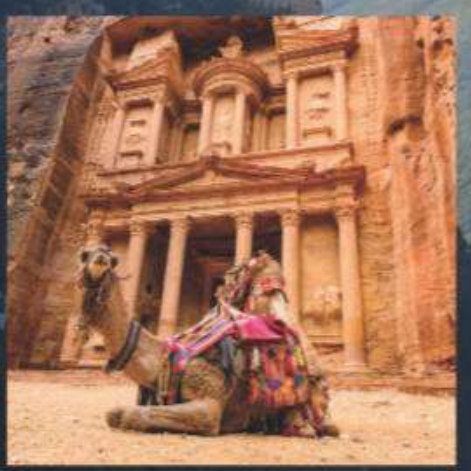

Ancient caves, human origins: Northern Spain

10 September 2024 | 7 days

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Retracing Charles Darwin's travels across North Wales

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- Learn about the human history behind Darwin's discoveries from Darwin expert Michael Roberts.
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The archaeological wonders of Jordan

30 September 2024 | 8 days

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- Travel the King's Highway between Amman and Petra.
- Take a jeep safari and Bedouin camp in the geologically fascinating Wadi Rum.

The geology of the Pyrenees: Spain

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ALWIN HARDENBOL

JORGE FONTES

Time for dinner

BMC Ecology and Evolution & BMC Zoology

A DRAMATIC chase is afoot between two seabirds above the icy waters of north-east Norway (far left). In a sly plan to steal a fish, an Arctic skua (*Stercorarius parasiticus*) tails a black-legged kittiwake (*Rissa tridactyla*) while mirroring its flight pattern.

The striking shot, captured by Alwin Hardenbol at the Swedish University of Agricultural Sciences, clinched top prize in the "Relationships in nature" category in the 2024 BMC Ecology and Evolution and BMC Zoology Image Competition. Kleptoparasitism (stealing food from others) is common among skuas.

Dipping below the water, a more chaotic scene is taking place off the coast of the Azores (near left). Schools of tuna, including the Atlantic bluefin (*Thunnus thynnus*), deftly herd "bait balls" of tiny snipefish straight into the mouth of a peckish whale shark (*Rhincodon typus*). The world's largest fish, whale sharks grow to around 12 metres long. Despite their size, they are gentle giants, usually eating plankton.

"But they're not feeding on plankton while they are in the Azores in the summer, because there's no plankton there," says Jorge Fontes, a marine biologist at the University of the Azores, Portugal, and the photographer behind this shot. The bustling snap was deemed the competition's overall winner.

"It shows how complex the ecological relationships between completely different types of animals [are]," says Fontes. "We realised the tunas and the whale sharks were cooperating, so there must be some sort of advantage for the tunas which we don't yet understand." ▮

Chen Ly

Earth's true nature

The Gaia hypothesis – that our planet is a living entity – is well known. But a dramatic twist to the story could help save the world, finds **Kat Austen**

Book

Becoming Earth

Ferris Jabr

Picador (UK); Penguin Random House (US)

GINKGOS were first planted in Seoul about 800 years ago. Today, over 100,000 of these giant trees take in carbon dioxide spewed out by the city's traffic, exhaling the oxygen humans need to live. It is a coexistence with which we are familiar, yet it exemplifies a principle beyond daily experience.

In *Becoming Earth: How our planet came to life*, science writer Ferris Jabr weaves a tapestry out of the complex relationships that life forms have not only with each other, but also with the stuff of Earth itself. As we travel with him, moving from the Amazon rainforest in northern Brazil and the tiny Siberian settlement of Chersky to a sunken mine shaft in South Dakota, we discover that Jabr sees our planet as a living entity. Just as our bodies comprise multiple organisms and chemical transformations, so, too, does the body of Earth.

For those who know a little about Gaia, the hypothesis put forward by chemist and inventor James Lovelock and co-developed with microbiologist Lynn Margulis, this idea isn't new. What stands out in Jabr's book, however, is his focus on the ever-changing state of the relationships that make our planet what it is today.

Central to this view is that humans and other living beings "are Earth – an outgrowth of its physical structure and an engine of its global cycles", writes Jabr. "Earth and its creatures are so closely intertwined that we can think of them as one."

The book's title also moves us there by evoking "becoming", a concept outlined by philosopher Gilles Deleuze, which argues that unceasing change is fundamental to existence. To show how this fits with the story of Earth, Jabr draws on research into its fiery formative years through to microbial mats – the earliest form of life – and on to today's climate catastrophe.

He visits many research sites, fitting them into a structure that covers rock, water and air, which mirrors the planet's elemental components and three of its four spheres – the lithosphere, hydrosphere and atmosphere.

"We are Earth – an outgrowth of its physical structure and an engine of its global cycles"

Jabr deftly draws links between processes at different scales. To discover how microbial action on the ocean floor may have created continents, he talks to researchers such as Robert Hazen, an earth scientist at the Carnegie Institution in Washington DC. At the other end of the scale, he meets Sergey Zimov and his family, who run the Northeast Science Station in Chersky, one of the Arctic's largest centres of science. Zimov's experiments show how the grazing habits of large mammals enlivened soil in the tundra.

Jabr also takes us to challenging sites, such as the plastic-strewn beaches of Kamilo, Hawaii. We see how Earth's complexity inevitably means that our actions have far-reaching consequences. So while plankton made Earth habitable for oxygen-loving organisms, our exploitation of their remains (fossil fuels) has created a climate crisis and plastic pollution.

Alongside formal research, he gives weight to the knowledge of groups such as the Indigenous Peoples of the Pacific Coast, which emphasises planetary complexity. These different forms of knowing let Jabr build a compelling account of interconnectedness. While human entanglement with the planet isn't limited to the recent industrial era, as a committee of geologists decided in rejecting the Anthropocene as an epoch, Jabr is clear that our unprecedented disruption to Earth's finely balanced systems is catastrophic.

And we can forget the much-discussed option of escaping to a new home, he says: it is unfeasible because we don't know enough. Instead, we should look to climate mitigation strategies, which governments – and crucially corporations – have the means to deploy. Not to do so would be an "unforgivable folly", he writes.

I am reminded of philosopher Donna Haraway, who urged us to accept the foolishness of human exceptionalism and embrace "becoming with" other species. Why stop there? With Jabr's guidance, we are becoming with Earth itself. ▮

KHANH NGHIA TRAN/ALAMY

Seoul's gingko trees help absorb the carbon dioxide produced by traffic

Kat Austen is an artist and composer based in Seoul, South Korea

Family viewing

David Attenborough adds authority to a film about a family of endangered orangutans in Sumatra, says **Jon O'Brien**

Film

Secret Lives of Orangutans
Silverback Films
Netflix

NETFLIX

Baby orangutan Emen will need some years of protection from his mother to survive

ONE of humanity's closest relatives, orangutans have provided some of the most memorable moments of David Attenborough's latter filmography. Who can forget the older female with her construction skills in *The Life of Mammals*? Or the sobering footage in *A Life on Our Planet* of one orangutan clinging on to the last remaining tree in an area gutted by deforestation?

Now, for the first time in his TV career, Attenborough has dedicated a whole documentary to these endangered animals. It is directed by Huw Cordey, who first worked with Attenborough on *Natural World*. *Secret Lives of Orangutans* was filmed in the western Indonesian island of Sumatra within its Leuser Ecosystem, an area of forest located in Aceh and North Sumatra. The island is home to about 14,000 orangutans, a figure predicted to decline by a third within the next decade. But in this film, the focus is on one small family – some of whom featured in the series *Our Planet*, also with Attenborough.

There is Friska, the 60-something matriarch who could win Olympic gold for sucking termites out of sticks, her daughter Ellie and, most notably, her granddaughter Eden, a spiky-haired 8-year-old who must now face the challenging ordeal of leaving the nest.

Ellie, the mother with whom Eden once shared an unbreakable bond (as we see in footage captured six years earlier), is more concerned with protecting her newborn, Emen, than with appeasing her eldest. Intercutting between this wide-eyed object of affection and a clearly envious Eden induces feelings of sympathy and smiles.

However, as Eden tentatively learns to fend for herself, her confidence grows. We see her amusingly getting rid of Olala, the youngest member of a rival family who briefly encroaches on her turf. And over the course of eight months, she forges a touching friendship with another orangutan, Sulli. Ellie's tough love approach may seem harsh, but it gets results.

Attenborough doesn't appear on camera, but his voice adds an authoritative and compelling presence, whether he is regaling us with remarkable facts, such as the discovery that orangutans can share their travel plans through their calls; philosophising about parallels with humans ("Looking at an orangutan, it's hard not to see something of ourselves"); or narrating the pratfalls and play-fights that occur within the lush Sumatran treetops.

Although more family-friendly than Attenborough's BBC fare, *Secret Lives of Orangutans* doesn't entirely shy away from moments when such physicality has far more serious consequences. Its subplot centres on a local battle for supremacy once a dominant male with the fabulous name of Split Lip Otto relinquishes his power. There is nothing to scar sensitive viewers, though: a slightly gouged cheek and a bruised ego are as bad as it get for poor Otto.

Indeed, with one eye on younger viewers, this Netflix original is often more like *Animals Do the Funniest Things* than a serious documentary: see how Eden's childlike cousin Pepito tries to banish a nonchalant turtle, for example. It isn't hard to imagine the film in a Saturday night line-up of light entertainment, and its whimsical soundtrack wouldn't be out of place on kids' TV.

Still, with drone technology allowing film-makers to get closer than ever to the Sumatran wild, the immersive cinematography of *Secret Lives of Orangutans* will leave older audiences spellbound, too. Its crash course on processional termites and the indigenous cemenang fruit feel may feel like tangents, but the film's 80-minute running time ensures that it doesn't outstay its welcome. File this in Attenborough's vast oeuvre under "loveable but lightweight".

Jon O'Brien is a writer based in Preston, Lancashire, UK

New Scientist *recommends*

Leah Crane
Senior reporter
Chicago, US

To me, one of the best parts of a thriller is the moment when the twist hasn't been revealed yet, but I have already figured it out. For that reason, I have to recommend **Dark Matter**, a new series on Apple TV+.

Starring Joel Edgerton and Jennifer Connelly (pictured below), this is a thriller in which a physics professor gets pulled into the multiverse, charging through various versions of Chicago in an attempt to get home. The very nature of the multiverse stands against him, as do other versions of himself. The show surfs along the edge of paradoxes, keeping it from getting

APPLE TV+

too bogged down in the physics of it all, and it is fun all the way through.

I have also been rereading, watching and listening to a bunch of iterations of the stories of Sherlock Holmes. Somehow every single one is good and they are all very different, so it has been easy to get into the groove of reading the original stories, watching **House** and **Sherlock** and listening to the **Sherlock & Co.** podcast all in a row.

The TV column

Playing war games

An unusual documentary follows US politicians and former generals as they react to a simulated attempted coup after a disputed election. It is fascinating – but leaves many questions unanswered, finds Bethan Ackerley

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on X @inkerley

THORSTEN THIELOW

US officials taking part in a 6-hour war game of an attempted coup

TODAY, I want to talk about a film. This is a diversion from our usual small-screen fare, but I recently watched a fascinating and frustrating documentary due to air on British televisions later this year – and I felt that is wiggle room enough for me to write about it. Beware a few spoilers to come.

War Game, directed by Jesse Moss and Tony Gerber, follows an unusual experiment. After the January 6 insurrection in 2021, when supporters of Donald Trump stormed the Capitol in an attempt to prevent the 2020 election result being certified, a group of officials sat down to test their preparedness for future unrest.

This 90-minute documentary is a glimpse into their 6-hour war game, which simulates an attempted coup following another disputed election. Politicians, former generals and members of the intelligence services role-play as figures in the presidential battle cabinet. It is as if the viewer is seated among them, with interviews and newsreel spliced in.

Set on 6 January 2025, fictional President Elect John Hotham (played by former governor of Montana Steve Bullock) and his advisers are faced with an almost identical scenario to 2021's attack on the Capitol. The key difference is that around 7 per cent of the US military is on the side of the insurrectionists, led by fictional Christian fundamentalist group the Order of Columbus, all of whom are rioting on behalf of Robert Strickland, whom Hotham has beaten by a slim margin.

The game highlights how there is a disproportionate problem with extremism in the US military. Deified as a group and abandoned as individuals, veterans have long lacked adequate mental health support, which far-right organisations have exploited. Groups like Vet Voice Foundation, the non-partisan organisation that convened this exercise, have picked up the government's slack.

"A fictional US president elect is faced with an almost identical scenario to 2021's attack on the Capitol"

As the war game continues, we meet Kris Goldsmith, an Iraq veteran who was once a prime candidate for radicalisation. In the simulation, he role-plays as a key member of the Order of Columbus, flooding social media with disinformation to destabilise the country. Goldsmith and his team are coolly competent, especially compared with the president elect's entourage, who ignore doctored images from the Order of Columbus for 3 hours and are ill-prepared to make key decisions, such as whether to invoke the Insurrection Act.

Chris Jones, a former marine who plays another agitator, comments that the US imagines itself particularly immune to insurrection. The abundance of guns in the country won't solve rising discontent, he says, but addressing the underlying issues will. We don't learn much about what those issues are, though. Nor do we see quite how the war game was devised or why certain strategies succeed or fail.

Instead, *War Game* apes the structure of a political thriller, but the tension is too frequently interrupted by interviews to gather steam. At one point, Hotham delivers a speech filled with barnstorming hokum, extolling the virtues of representative democracy. Set to triumphant strings, it could have been an episode of *The West Wing*.

Only at the debrief is the team's ebullience punctured – Goldsmith is visibly angry at the prevailing conclusion that the US is well-prepared in real life.

I left *War Game* with questions about the exercise's purpose. I didn't learn much and I'm not sure anyone in the situation room did either. That said, for capturing the precarity of the US government in such scary circumstances, this is worth your time. ▮

Documentary

War Game

Jesse Moss and Tony Gerber

Coming to UK television later this year; in select US cinemas

Bethan also recommends...

Film

Civil War

Alex Garland

A group of photojournalists led by Lee (Kirsten Dunst) try to interview an embattled three-term president while the US is overwhelmed by conflict.

TV series

The West Wing

Aaron Sorkin

Look, I'm not made of stone. The magic of Sorkin's fast-talking, corridor-walking White House drama isn't lost on me, even if parts of its politics ring hollow in the current political climate.

Editor's pick

Getting to the heart of what makes us human

3 August, p 32

From Garry Marley, Stillwater, Oklahoma, US

Colin Barras correctly concluded that the line between human and non-human tends to be as much philosophical as biological. I am reminded of a subtle behavioural distinction made by physicist Brian Greene when he noted that humans transcend their timeline. This parallels something a philosophy professor told me long ago: humans ask what came before their forebears. This inspires oral histories, myths and legends. Then humans unavoidably inquire: what happens after our deaths, both personally and to our society? "We know we are going to die," Greene starkly summarised it. Regardless of cerebral cranial capacity, tool-making skills or limb dimensions, those criteria comport with our humanity.

From Terence Denman, Totnes, Devon, UK

When did we become human? When we got language. Everything distinctively human – art, philosophy, technology, religion and so on – is predicated upon it. But its arrival has always been a conundrum for human evolution.

First, there is nothing close to our sophisticated language in the animal world. Second, why did we need such an incredible tool? We could have been successful and dominant with a signalling system only slightly more refined than that of the other primates.

As for hard evolutionary evidence of when language began, you can look at bones all you like, but, with rare exceptions, brains don't fossilise. We can, perhaps, look at the development of early human-like culture, but the dating there is imprecise. The arrival of language is a problem that, as Noam Chomsky has observed, may be forever a mystery.

Should horses be in the Olympics at all?

10 August, p 21

From Graham Barker, London, UK

Christa Lesté-Lasserre discusses the furore over a horse being whipped while training for dressage events, but doesn't address the major concern: why make a horse dance to order? If animals are unwelcome in circuses, why make a horse dance carrying a rider and call it a sport? Why "train" a horse to jump a very high fence for events like showjumping when an "untrained" one would be happy with no more than 2 or 3 feet? Why are horses in the Olympics at all?

Lunar repository could store frozen bodies, too

10 August, p 14

From Alex McDowell, London, UK

You report on a proposal to put a frozen backup of Earth's life on the moon. The idea of off-planet reserves for life, albeit not frozen, isn't new. In the 1972 movie *Silent Running*, forests are kept in giant greenhouses beyond the orbit of Saturn. In any event, any lunar repository could be financed by wealthy people who wish to have their bodies cryogenically frozen.

Painful memories of impact force physics

10 August, p 18

From Richard Brown, Huntly, Aberdeenshire, UK

Alex Wilkins reports that a slight curve on the surface of a rock helps it make the biggest splash. I am of a generation that received corporal punishment. It was well known that the more charitable disciplinarians used an absolutely flat instrument. We, the recipients, could feel the reason suggested in the research: the flat surface formed an air cushion at the point of impact. By contrast, even slight curvature of the impact surface transmitted much more force.

Running errands once kept children active

27 July, p 42

From Anne Sweeney, Maidenhead, Berkshire, UK

With reference to childhood exercise, an additional factor struck me. As a child in a car-less household, I was frequently presented with a purse and a shopping bag and told to run and fetch whatever was needed from the local shops, thus clocking up both aerobic and weight-bearing benefits. My own children, however, just pop in the car to the supermarket while the grandchildren sit on the sofa, so maybe lifestyle has a significant impact on how much exercise children really get.

Could unlikely galaxies be from another universe?

3 August, p 36

From David Keyworth, Southampton, Hampshire, UK

I read your article on attempts to detect very early structures in the universe with interest, and was taken by the line "the further back into cosmic history we have looked, the more astounded we have been to see nigh-on fully formed galaxies and supermassive black holes that shouldn't exist because there hasn't been enough time for them to form". Can we rule out that what we are seeing isn't a sign of another, earlier universe into which we are expanding, which had time to form such features?

Perhaps American settlers butchered thawed meat

27 July, p 18

From Tom Heydeman, Reading, Berkshire, UK

You report that butchered bones hint at earlier human arrival in South America. But could the butchered glyptodont, which has been dated to the last glacial maximum period, have become frozen after death, like a Siberian mammoth, and likewise thawed thousands of years later and been butchered then?

Unfair advantages in other contests

Leader, 3 August

From Martin van Raay, Culemborg, The Netherlands

You speak of doping in sports as an unfair advantage. I agree. But a few pages later in the same issue (p 11) you report that a Google AI has achieved a silver medal score in a human mathematics competition.

Considering that a computer uses much more energy than a human brain, could you call that doping? And should the AI be disqualified or at least banned from competing until it uses as little energy as my brain does?

Mathematical poetry taken to the next level

10 August, p 44

From Steve Parkes, Uttoxeter, Staffordshire, UK

As a bit of a poet and a bit of a mathematician (and no great shakes at either), I found Peter Rowlett's piece on mathematics and rhyme entertaining, especially the notion of the pi-ku, a haiku variant with syllables based on 3.14 for its three lines, i.e. 3, 1 and 4. Why stop there, when there are many other mathematical constants? How about a phi-ku using phi (1.68) or an *e*-ku using *e* (2.72)?

One of my pi-kus: For circles / π / vital constant. And a phi-ku: Gosh! / 1 subtracted from phi / is the same as 1 over phi. ▮

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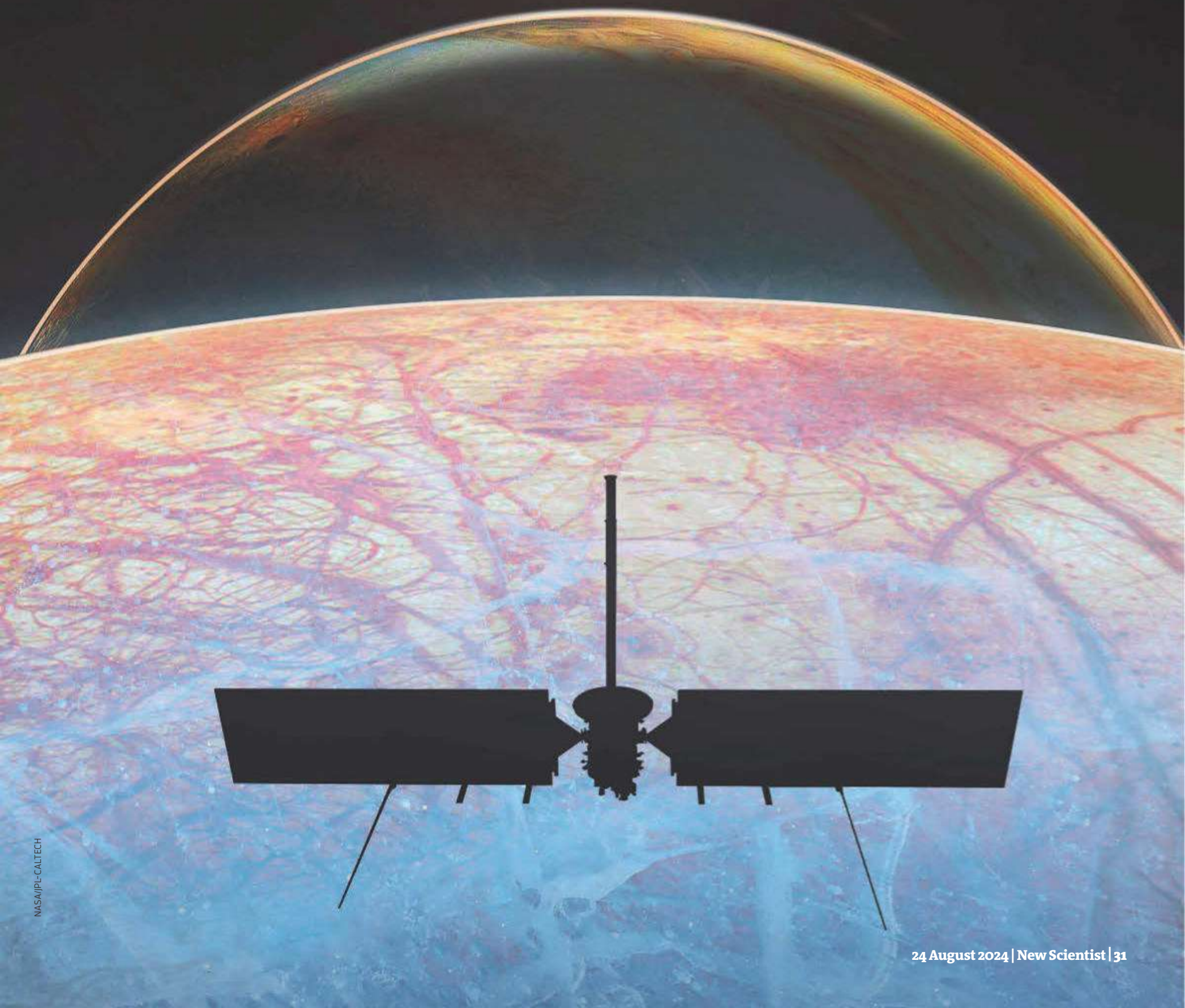
Mission to Europa

A NASA probe is about to set off for one of Jupiter's icy moons to see if it could harbour life. What's so special about Europa and what exactly are we looking for, asks **Abigail Beall**



NASA/JPL-CALTECH

SEEN against the backdrop of Jupiter's dramatic, swirling atmosphere, Europa might at first appear a bit drab. With its greyish-white surface, you might even say it resembles a well-worn cue ball in a run-down pool hall. On closer inspection, however, the Jovian system's fourth-largest moon is shimmering with intrigue from deep within.

From what we can tell, its icy outer layer conceals a vast global ocean containing twice the volume of water on Earth. This, in addition to hints of geophysical activity – such as the rusty lines that streak its surface – and complex chemistry, is why Europa has long captivated astronomers searching for habitable worlds beyond our pale blue dot. So could Europa have the conditions for life? We're about to find out.

In October, NASA will launch Europa Clipper, a $5 billion probe that will get a closer look at the moon's geology and chemistry – and, with any luck, identify the telltale signatures of habitability. The mission has been decades in the making, building on previous forays that have thrown up tantalising clues as to what lurks inside the moon's frozen shell – and no shortage of questions.

Clipper promises answers. It will study the moon's surface and the ocean hidden beneath in unprecedented detail. It could even sample the water in plumes of vapour if, as we suspect, they are erupting from Europa's surface. And although it isn't designed to find direct evidence of life – a bacterial cell, say – recent developments suggest there is a fleeting chance it could do exactly that. "With Europa Clipper, we're really entering a new phase of astrobiology," says Sam Howell, a project staff scientist on the mission.

We first laid eyes on Europa in 1610, when the astronomer Galileo Galilei spotted four worlds orbiting Jupiter. These days, we know of more than 90 moons in the Jovian system. Europa has held a particular fascination, though, partly because its icy surface is remarkably crater-free – evidence that below the hard exterior is a dynamic world, with geological processes constantly reshaping its surface.

Like all of Jupiter's innermost moons, Europa is stretched and squeezed by the gravity of the giant planet. As its oval-shaped orbit brings it periodically nearer and farther from Jupiter, a gravitational tug of war flexes the moon's interior, creating friction that warms it from the inside in a process called tidal heating. But it wasn't until we got up close, when NASA's Galileo probe visited in the 1990s, that we realised what that meant.

Europa Clipper under construction at NASA's Jet Propulsion Lab in California

Nobody had expected there to be liquid water on Jupiter's icy moons – let alone an enormous ocean. These worlds lie more than 750 million kilometres from the sun, after all, with surface temperatures of around -160°C (-184°F). But Europa defied this assumption when the Galileo mission discovered it had a secondary magnetic field.

The only way this could be so is if Jupiter's own magnetic field interacts with something conductive inside the moon. The most plausible explanation is that Europa hides a salty ocean beneath its icy crust, kept from freezing by the tidal heating. "We really weren't expecting that," says Kathleen Craft at Johns Hopkins University in Maryland, who is part of the Europa Clipper mission.

It gets more intriguing, though, because further investigations revealed that Europa could well have all the ingredients needed for life: not only a liquid ocean but also essential chemicals and energy, in the form of radiation from Jupiter. "The ocean may be an ideal environment to harbour primitive life, having conditions similar to those in Earth's thermal vents in its deep oceans, where life may have arisen on our planet," says Bonnie Buratti, deputy project scientist for the mission.

Planetary scientists would love nothing more than to sample that water directly. That might just be possible because there are reasons to think that Europa may be venting plumes of water vapour into space.

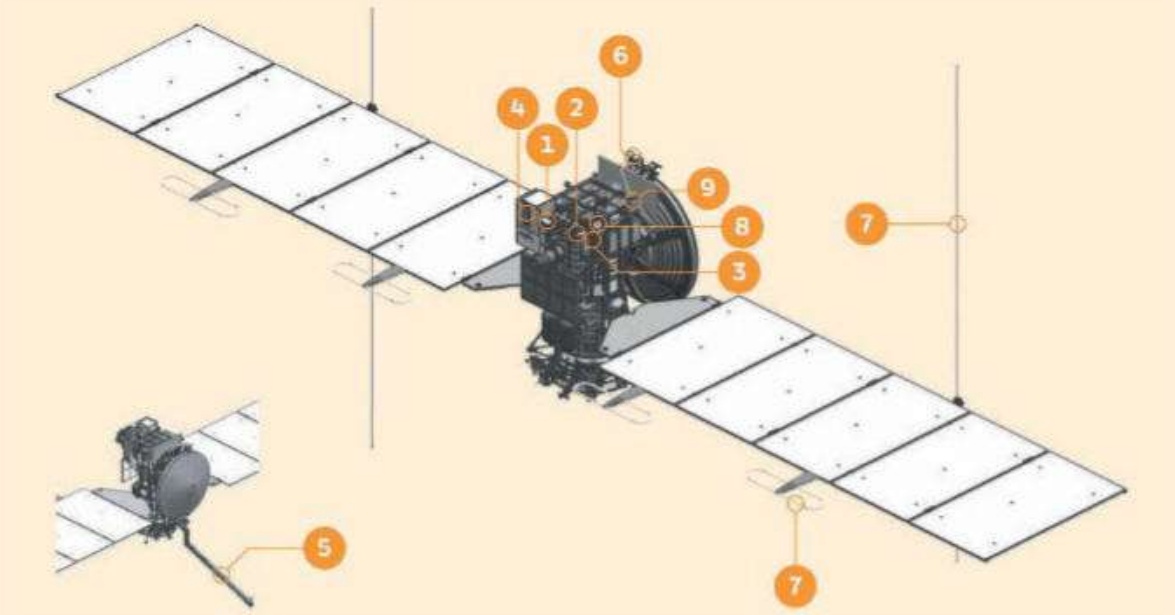
In 2005, the Cassini spacecraft discovered that one of Saturn's moons, Enceladus – which is less than a sixth of Europa's diameter – was shooting plumes out of its south pole. "That was also kind of crazy, because it's this tiny ice ball but it had all this activity," says Craft.

In 2012, the Hubble Space Telescope spotted hints of something similar on Europa. Spectral imaging revealed a large cloud of hydrogen and oxygen atoms – most likely in the form of water – spewing from the moon's south pole. Then, in 2018, a new analysis of Galileo data collected in 1997 found a sudden shift in

NASA/JPL-CALTECH

Meet the probe

Europa Clipper features nine scientific instruments, each designed to offer insights into the suspected ocean beneath Europa's frozen shell and the prospect of life there



1 **Europa Imaging System (EIS)**
Two 8-megapixel cameras to produce high-resolution pictures

2 **Europa Thermal Emission Imaging System (E-THEMIS)**
To distinguish warmer regions where liquid water may be near or on Europa's surface

3 **Ultraviolet Spectrograph (Europa-UVS)**
To determine the composition of the moon's atmosphere and search for signs of water plumes

4 **Mapping Imaging Spectrometer for Europa (MISE)**
To map the distribution of ice, salts, organic compounds and warm spots

5 **Europa Clipper Magnetometer (ECM)**
To confirm the existence of Europa's subsurface ocean and measure its depth and salinity

6 **Plasma Instrument for Magnetic Sounding (PIMS)**
To further study Europa's ocean

7 **Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)**
Ice-penetrating radar to study the structure and thickness of Europa's icy shell

8 **Mass Spectrometer for Planetary Exploration/Europa (MASPEX)**
To analyse gases in Europa's faint atmosphere and possible water plumes, plus study ocean chemistry

9 **Surface Dust Analyzer (SUDA)**
To identify the chemistry of any materials being ejected from Europa's surface

Europa's magnetic field that could also indicate a cloud of water coming out from its surface. Any plumes, if they do exist, seem to be weaker than those on Enceladus. "Its plume activity is pretty constant, but what we think for Europa is it might be more periodic," says Craft.

Whether or not there really are plumes on Europa is far from the only mystery. There is much we still don't know, not least the depth and salinity of its putative ocean and what kind of chemistry it might contain. To find out, we need to get a closer look, which is where Clipper comes in.

This is NASA's fourth flagship mission to the outer planets. With a launch window opening in October this year, the spacecraft will reach the Jupiter system in 2030. There, it will orbit Jupiter and perform a series of flybys of Europa, using the nine instruments it carries (see "Meet the probe", above) to figure out whether this moon really does harbour conditions conducive to life.

> "Further investigations revealed that Europa could well have all the ingredients for life"

Clipper's magnetometer will carefully study the strength and direction of Europa's magnetic field, as well as how it varies over time. Combined with measurements of how the high-energy plasma around Europa moves, this will allow us to piece together how much of the magnetic field is generated by electrical currents within Europa's ocean. "By sensing the magnetic field around Jupiter and around Europa, we can tease out properties of that ocean like how salty it is and how deep it is," says Howell (see interview, page 34).

Radar and magnetic field measurements will reveal the thickness of Europa's icy crust to help pinpoint places where the ocean is close to the surface and potentially escaping. Combined with high-resolution photographs, temperature data and analysis of Europa's surface and atmosphere in ultraviolet and infrared, Clipper will also solve ongoing mysteries around what is happening on the surface.

This includes identifying relatively warm spots, which could indicate recent geological activity, and looking for molecules that could have been brought to the surface by sea water, such as carbonates and sulphates. "It's important that we understand the surface landforms and what those tell us about the exchange of material from the surface to the ocean and the ocean to the surface," says Howell.

This exchange of material is fundamental to the kind of chemistry we know underlies life on Earth, and which we believe could be going on inside Europa. It has to do with interactions between reducing agents – molecules with electrons to give away – and oxidising agents, which want more electrons. On Europa, the ›

New Scientist video
Watch the full interview with Sam Howell **newscientist.com/video/**

reducing chemistry could happen at the sea floor, caused by interactions with the salty ocean, while the oxidising chemistry could happen on the surface, caused by radiation interacting with water or sulphur.

That is why we're so keen to study surface features known as chaos terrain, which look like they are made of ice that has been broken and moved around. "It almost looks like icebergs getting tossed and turned," says Craft. "Those are places where maybe liquid water has come closer to the surface to allow that overturning of the blocks of ice."

It is also why Europa's putative plumes hold so much intrigue – they could give us a direct look at what kind of chemistry might be going on. And the good news is that if water is bursting out of the subsurface into the atmosphere around it, Clipper's instruments will have the chance to "taste" it.

Signs of life

None of which is to say that anyone is expecting to find evidence of life. "Europa Clipper is not a life-detection mission," says Buratti, echoing what everyone involved is at pains to point out. "It is instead seeking a habitable environment where life might exist." And yet there might well be a chance – albeit a slim one – that it could detect life after all, thanks to the spacecraft's dust detector.

"Europa is shrouded in a very tenuous atmosphere of ice grains from micrometeorites that impact the surface," says Fabian Klenner, who works on the instrument, which is called the Surface Dust Analyzer (SUDA). As Clipper flies past Europa, it will be splattered with dust, ice and gas coming from the moon's surface. "It's a paradise for the SUDA instrument, because it just flies through these grains and analyses them individually."

Using a mass spectrometer, SUDA will reveal the different kinds of ice that Europa's surface is made of. We know it is mostly water ice, but there are other compounds there too. While we have an idea what these might be, SUDA will confirm what kind of salts and organic material, if any, are present. "I'm very curious to understand the organic inventory of the moon," says Klenner, "which is very important to Europa Clipper's mission goal to investigate if Europa is able to support life or not."

The idea that we might do better than that comes from an experiment published in March, in which Klenner and his colleagues set out to test whether, if there were fragments of life floating in the ice grains around Europa, SUDA could find them. To replicate what will

'One day we might look for life directly on Europa'

Sam Howell is a project staff scientist on NASA's Europa Clipper mission and a planetary interior researcher at NASA's Jet Propulsion Laboratory in Pasadena, California. He tells David Stock why the agency is so keen to visit Jupiter's fourth-largest moon and what exactly it is hoping to find there.

David Stock: Why is this probe such a big deal?
Sam Howell: Europa Clipper is in a special class of mission. Historically, NASA has sent three "flagship" missions to the outer solar system. These have fundamentally changed our understanding of the solar system. We had the twin Voyager probes beginning in the 1960s and 1970s, we had the Galileo mission in the late 1990s and early 2000s, and we had the Cassini mission, which recently finished its grand finale at Saturn.

Now, we're going back to Jupiter. The fourth outer solar system flagship mission, Europa Clipper, is going to specifically look at one of the four largest moons of Jupiter, Europa, to find out if it has the conditions necessary for planetary habitability.

Why is this such a promising place to look for signs of the potential for life?
Europa is about the size of our moon and most of it is rock, but the entirety of the world is covered in about 100 kilometres of water. The top maybe 20 km is solid ice and then there is a saltwater ocean, we think, underneath that surface.

We think that life might have originally emerged on Earth in hydrothermal vents on the seafloor [thought to have had the right conditions to generate organic molecules and life-friendly energy]. If you have similar vents on the ocean floor of Europa, that gives you one half of what you need for life, the molecules. The other half, energy, could come from the radiation of Jupiter interacting with Europa's ice.

What are the most interesting parts of Europa to look at in terms of this?
Central to the story of habitability on Europa is our belief that the salty ocean could interact with the seafloor to produce lots of reducing chemistry – that's chemistry in which electrons are given away. And we believe that the radiation at the surface interacting with water, and even with sulphur, could produce strong oxidants – that is, things that want electrons.

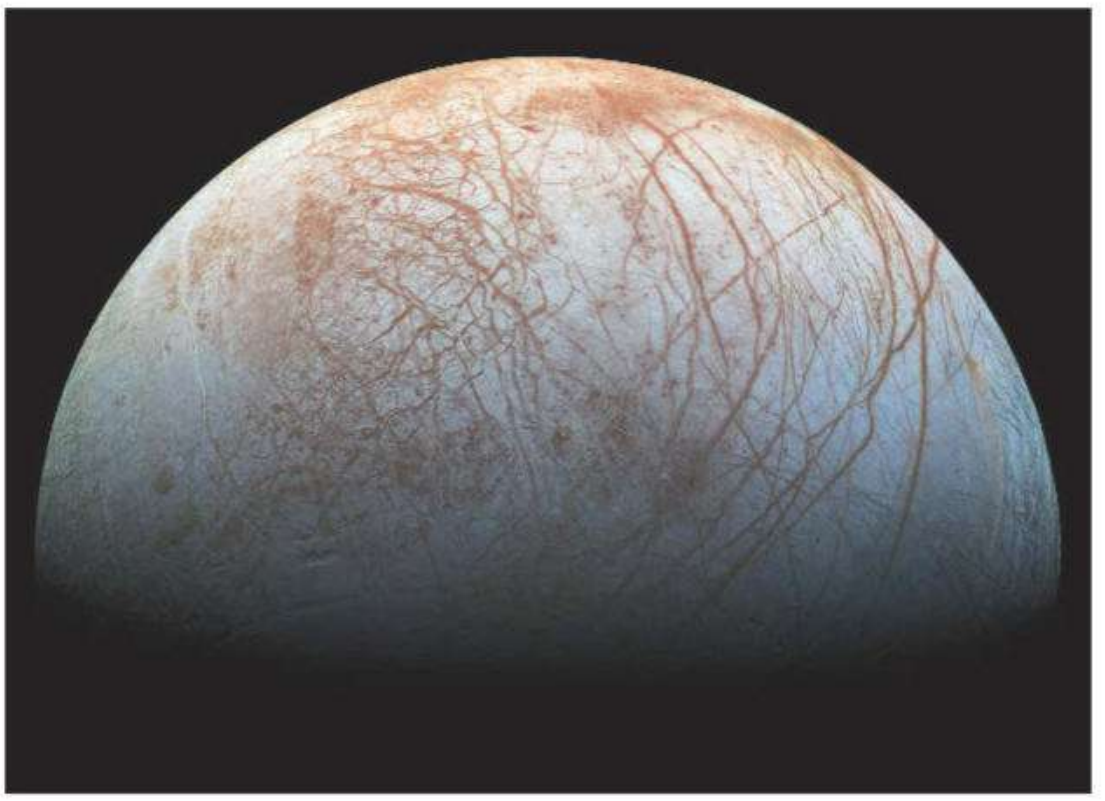
All the life that we know of here on Earth uses the transfer of an electron as its most basic energy source. So what we're really interested in is the place where these oxidants and reductants come together.

How exactly is the probe designed to study the ocean and the surface?
On board the spacecraft we have nine instruments (see "Meet the probe", page 33) and one experiment. Together, they will observe Europa not only in visible light, but in infrared and thermal infrared and in UV, and even with an ice-penetrating radar. We will have in situ instruments that can measure the environment directly.

There is also a dust analyser that can pick up material that has been sputtered off the surface by micrometeorite impacts and "taste" solid material ejected from Europa directly. We will also have a mass spectrometer capable of understanding the atmosphere of Europa and a magnetometer that can infer the size and salinity of Europa's ocean by its interaction with Jupiter's magnetic field.

What will those instruments tell us?
We're going to be exploring what processes we think are active in the ice shell today. So we are looking for recent and current activity – everything from where there might be active tectonic faults to where there might be eruptions of water vapour from water trapped within the ice shelf. We are also going to probe the interior.

It will really provide us with new insight into the sorts of environments on Europa where we think life might emerge, if someday we want to explore them. There are already numerous technologies and mission concepts being developed that might one day look for life directly.



NASA/JPL-CALTECH/SETI INSTITUTE

NASA/JPL/UNIVERSITY OF ARIZONA

Reddish streaks (left) and "chaos terrain" (below) on Europa suggest geological activity

happen during the flybys, where ice particles will collide at high speeds with the instrument and become ionised, they fired a water jet at the same speeds Clipper will be travelling – around 4 to 6 kilometres per second – onto a replica of SUDA. They used a laser to ionise the molecules, breaking them up into their constituent parts.

Surprisingly, they found that if there were any extant cellular life within the ice particles, SUDA would be able to spot it. It is a huge if, to be clear. First, you would need to have life in the ocean. Then, plumes or other mechanisms would have to waft that life up from the depths to the moon's surface. Finally, you'd have to be lucky enough to catch it.

"Imagine you have a very interesting sample, let's say it's a bacterial cell," says Klenner. It might be that only a few out of every 1000 ice grains contain such a cell. Over the course of one flyby, SUDA will analyse a few thousand ice grains individually. "If you find, with a bit of luck, one of the ice grains with a bacterial cell in it, then SUDA can tell you that this single grain had the bacterial cell in it."

The speed also matters. Too slow and you don't have enough energy to ionise the compounds, too fast and you shatter the molecules. "It's really cool that the Goldilocks zone for retention of interesting compounds is 4 to 6 kilometres per second," says Klenner. "This is exactly what Europa Clipper will do."

The most likely scenario is that SUDA and the other instruments on Clipper won't find evidence of life directly, but they will instead point us to zones where we might be able to find it, perhaps places where the ice sheet is thin or water is escaping. This too is vital because it could lead to a series of future missions to land on the moon and ultimately drill into the icy crust and even right into the hidden ocean below.

"Most likely, we'll have a lander first," says Craft. This could be a robot that can get under the surface of the moon, perhaps several metres. It might not get into the water itself, but it could still have a chance at identifying molecules from the ocean. "There is the potential that slow convection brings ocean material up towards the surface," says Craft, "just like our mantle and crust overturns on longer timescales." Europa Clipper will thus be looking for places where this is evidence of seawater recently coming to the surface, should they exist.

Next, the plan would be to send a submersible robot, known as a cryobot, through the ice into the water. NASA hasn't yet firmly decided to support any lander or drilling missions to Europa, but Craft and others are already sketching out how the concept might work. The cryobot would drill into the ice, powered by nuclear fission, melting its way down and taking samples as it goes. "Life as we know it loves interfaces," says Craft, so the most exciting place to study would be the boundary between the ice and the water.

> "Europa Clipper could ultimately lead to a series of missions to land on this moon and drill into its icy crust"

Again, Europa Clipper will pave the way for such a mission by mapping where the ice is thinnest, providing the best chance of getting to the water. If it confirms the ice to be as thick as we expect – that is, a few kilometres to a few tens of kilometres – drilling could take between three and six years. It will be slower than on Earth, owing to gravity being far weaker on Europa.

The final step in exploring the moon would be to find and investigate any hydrothermal vents at the bottom of its ocean. "Europa's ocean is very deep, but if we could ever get to the seafloor, that would be an extremely interesting place," says Craft.

We have only just started to scratch the surface of our own oceans – life around hydrothermal vents was discovered in the 1970s. So the challenge of finding our way around a 100-km-deep ocean, billions of kilometres away, is a daunting one. With Clipper's launch, however, we are at least dipping our toes in the waters of a distant ocean world. ▮

Abigail Beall is a features editor at *New Scientist*

Caffeine: The unfiltered truth

How worried should we be about our love for coffee and energy drinks? **Jasmin Fox-Skelly** investigates

MARCOS MONTIEL

"I ONLY drink coffee on days ending in y," so the saying goes. If this mantra applies to you, welcome to the club. Coffee's best-known component, caffeine, is estimated to be the most widely used psychoactive drug in the world, with billions of people consuming it every day. But unlike other addictive substances, it is largely unregulated, and nobody would flinch at the idea that you might struggle to function without it from the moment you wake up.

Coffee lovers might be on to something, with a slew of studies showing that, taken in the right way, caffeine can improve many things, not least your cognitive abilities and alertness. What's more, your pursuit of a Java pick-me-up may bring a host of related health benefits. Yet not all sources of caffeine are viewed equally. In recent months, its health risks, especially when in energy drinks, have been in the spotlight again. In June, the UK Labour party, which now forms the country's government, pledged to ban the sale of these drinks to children under 16 due to their "dangerously high" caffeine content. This comes hot on the heels of a comprehensive report called *The Dark Side of Energy Drinks*, which documents cases of people who ended up with severe health issues after consuming them.

Dosing is another concern. We don't all respond to it in the same way – what is safe for you might not be for others. It can be a confusing picture, but unpick the research and you can find ways to use your caffeine cravings

to your advantage, without the downsides.

Caffeine is a natural compound found in the seeds, fruits, nuts and leaves of around 60 species of plants, with its bitter taste an evolutionary quirk related to its role as a natural pesticide.

The discovery of its richest natural source, coffee, is said to go back to Ethiopia around AD 850, when a local goat herder noticed his animals getting jumpy after eating berries from an arabica plant. He gave some of the fruits to a local monk, who brewed the world's first cup of coffee.

We now know this jumpiness boils down to caffeine's effect on the brain. It only takes around 45 minutes for all the caffeine from a cup of coffee to be absorbed into your circulatory system, where it travels to the brain, easily crossing the blood-brain barrier. Here, it binds to and blocks receptors for the neurotransmitter adenosine. This chemical builds up as the day goes on and dampens nerve fibre activity to make us sleepy. "It slows us down," says Jennifer Temple at the University at Buffalo in New York. "Caffeine competes with adenosine for access to the receptor, so it has the opposite action – it makes us feel more energetic, alert and awake."

A shot of focus

As anyone faced with a deadline or long drive knows, this has its benefits. Research backs up what coffee drinkers already appreciate: people who downed a shot of caffeine had shorter reaction times and were more alert, focused and cognitively sharp. The effects were physical, too, with better performance in tests of muscle strength, endurance and high-intensity sprints. A recent study of amateur cyclists found that caffeinated coffee improved performance by an average of 1.7 per cent. Such effects tend to last for around 2 hours, although this varies considerably between people and will also be influenced by other factors like the food you ate recently.

Given these findings, it is little wonder that caffeine's presence in energy drinks in particular is often marketed as a way of focusing attention, improving exam performance and enhancing athletic prowess.

There are other effects, too. After people consume caffeine they tend to report feeling happier, and there are signs that this substance could even cause a longer-term mood boost. For example, studies consistently show that individuals who drink three to four cups (or shots) of caffeinated coffee a day are less likely to experience depression and have a lower risk of suicide. However, the same relationship hasn't been shown with decaffeinated coffee, suggesting that caffeine itself is responsible.

"The results are quite robust, which is almost surprising because you don't think of caffeine as being a potent antidepressant," says Alberto Ascherio at Harvard University.

His work and that of others have also found that drinkers of caffeinated coffee have a significantly lower risk of developing Parkinson's disease. Although the reason for this is unclear, Ascherio points to caffeine's known ability to increase levels of the neurotransmitter dopamine in the brain. Dopamine plays a vital role in regulating the movement of the body and a lack of it has been implicated in both Parkinson's disease and depression.

More good news for coffee drinkers is that consuming it seems to bring a host of benefits that aren't necessarily anything to do with its most famous component. Purported heart health benefits are a good example, something that, for a long time, wasn't considered possible with caffeinated coffee at all. "Because there were quite a few reports that caffeine sped up your heart rate and gave some people palpitations, everyone assumed coffee was bad for you," says Tim Spector at King's College London.

In a recent study led by Peter Kistler, a cardiologist at the Baker Heart and Diabetes Institute in Melbourne, Australia, more than 380,000 people in the UK were tracked for 10 years to see if they went on to develop cardiovascular disease. People who drank two to three cups of coffee a day generally had a lower risk of developing coronary heart disease, heart failure or arrhythmias, or of dying for any reason during the study period. However, decaf drinkers saw, by and large, the same benefits (with the exception of arrhythmias), suggesting it is something else in coffee that is responsible for its heart-protective effects. "The sweet spot seems to be around three ›

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cups of coffee, which is associated with a 25 per cent reduction in heart disease and a reduction in all-cause mortality," says Spector.

It should be noted that correlation isn't causation. Most of the studies are epidemiological, which means they involve tracking very large numbers of people over time to see if they go on to develop certain diseases. When it comes to coffee drinking, there are few randomised controlled trials – the gold standard of medical research – because it is very difficult to control for other dietary factors. However, a few such trials have shown that you can reduce biomarkers of heart disease by giving people coffee.

If caffeine isn't behind this particular upside of consuming coffee, what is? The answer lies in the drink's complex nature. Prior to roasting, coffee beans are fermented, which influences the spectrum of biologically active compounds the final drink can contain. These include polyphenols – chemicals made by plants to protect themselves against environmental stresses, such as predation by insects and extreme temperatures – which are thought to have antioxidant and anti-inflammatory effects on the body. Coffee is also high in fibre, a beneficial dietary component that most people don't get enough of, often associated with a healthy gut microbiome.

"Two to three cups of coffee a day should be considered as part of a healthy diet"

Spector believes the gut microbiome may ultimately be behind some of coffee's positive effects on health. In a study that is yet to be published, he and his team collected stool samples from more than 30,000 people from different countries. They identified a particular bacterium, a type of *Lawsonibacter*, which is found almost exclusively in the guts of people who drink coffee, including decaf. "You basically have five times the amount of this microbe if you're a coffee drinker compared to a tea drinker," says Spector (see "Time for tea", right). "It's really interesting because it's the first time we've ever found a microbe that is so fussy. It only eats one type of food. It's the most specific food-microbe association that's ever been reported."

The more coffee you drink, the more your gut will be dominated by *Lawsonibacter*. This is a good thing, because when these bacteria feed on the fibres and polyphenols in coffee, they release chemicals called short-chain fatty acids that are known to be anti-inflammatory, calming the immune system.

This could explain the reportedly wide-reaching health benefits of coffee. Chronic inflammation is thought to be the main driver of heart disease. Coffee consumption has also been associated with lowered risk of diabetes, obesity and allergies, which are also thought to be aggravated by inflammation, as is depression. "Virtually everything – even mental health – is probably related to low-level inflammation of some kind," says Spector. "So it's really important that you have these continuous signals [from the immune system] saying, don't worry about this, we've got it under control. Otherwise, the body thinks it's under attack."

Altogether, then, there is robust evidence that caffeine, and more broadly coffee, can be beneficial. "What I would say is that the evidence suggests that if you are a coffee drinker, there is no reason to stop, and that all the data I've looked at shows that two to three cups of coffee per day should be considered as part of a healthy diet," says Kistler.

Other research, however, might kill that buzz. Like many things, especially psychoactive substances, it is possible to have too much of a good thing. Today, we don't need to rely on natural sources to get our caffeine hit. The stimulant can be synthetically created and added to soft drinks, energy drinks, supplements and even medicines. The concentration of caffeine in these varies hugely and is often equivalent to a cup of coffee, but is sometimes much higher.

Potent mixture

Taken in high doses, caffeine causes the adrenal glands to ramp up production of the hormones adrenaline and noradrenaline, activating the body's fight or flight response. "Your pupils dilate, you start to sweat and your heart rate and blood pressure increase," says Margaret Thompson at the Ontario

Time for tea

Tea has long been considered a healthy drink, with proponents claiming it could boost your immune system, dampen inflammation and even ward off cancer and heart disease. But does the evidence stack up? Where better to find out than in the UK, renowned as a nation of tea lovers?

One recent study tracked 500,000 tea drinkers there over 11 years. It showed that drinking two to three cups of black tea a day was associated with a modest 9 to 13 per cent lower risk of death. Higher tea consumption was also associated with a lower risk of death from cardiovascular disease, ischaemic heart disease and stroke.

However, green tea, which is made from unfermented leaves, may be even better. It is richer in polyphenols, which act as powerful antioxidants. These disarm and neutralise reactive chemicals known as free radicals, which destroy cells and DNA.

"Based on the current evidence, black tea – which most English people drink – is not as healthy as coffee and doesn't have the same benefits, particularly on the heart," says Tim Spector at King's College London. But if coffee (see main story) isn't your, ahem, cup of tea, you might want to consider green tea instead to reap similar health benefits.

DAN KITWOOD/GETTY IMAGES

Coffee can improve your health, not just your look

Poison Centre in Canada.

It was concerns over "dangerously high" caffeine content that led the UK's Labour party to pledge to ban energy drinks for children under 16 earlier this year. Now in power, it has proposed legislation to restrict their sale. Energy drinks are particularly popular with young people, with up to half of children worldwide estimated to drink them on a weekly basis. And Temple's work has found that the combination of caffeine and sugar in them make them especially hard for children to resist, sometimes with risky consequences.

"When people overdose on caffeine, they usually present to emergency departments as agitated, excitable and anxious," says Thompson. "The agitation can progress so far as to actually cause seizures, and they often complain of palpitations; they feel like their heart is beating abnormally or too fast."

More problematic still, according to *The Dark Side of Energy Drinks*, is that these products often contain other legal stimulants, such as guarana, taurine and L-carnitine. Some of these act to further increase blood pressure, heart rate and breathing rate. The case studies in the report make for sobering reading, with examples of people experiencing serious cardiac events after consuming energy drinks.

"While the scientific community is knowledgeable about the pharmacology and effects of caffeine, much less is known about the interactions among all the ingredients and their long-term effects related to chronic consumption," says Andrea Costantino, a doctor now at the Careggi Hospital in Florence, who co-authored the report.

To make matters worse, sensitivity to caffeine varies wildly. Some people can guzzle three cans of energy drink in quick succession with little effect, while others aren't so lucky. This is at least in part due to the fact that there are many variants of the adenosine receptor across the human population, says Temple. Once people become habituated to caffeine, they also need more of it to get the same buzz.

Perhaps unsurprisingly, children who drink caffeine, particularly later in the day, take longer to fall asleep at night, sleep for less time and have poorer-quality sleep overall than children who don't drink caffeine.

The clear message, then, is that energy drinks – and to a lesser extent fizzy caffeinated beverages – can be bad for your health. "Energy drinks are ultra-processed and full of sugar, artificial sweeteners, artificial flavourings and all kinds of other preservatives and chemicals. So they have nothing good to offer at all," says Spector. If you must drink them, as a rule of thumb Costantino recommends that adults stick to one can at a time, with a maximum of two per day to remain within an acceptable safety limit.

As for coffee, the chief source of caffeine for many people, the findings suggest that most of us could benefit from drinking around three cups a day. While there are fewer long-term studies of decaf, the few there are show it may be just as effective at warding off heart disease and diabetes. However, if you want to lower your risk of depression and Parkinson's, then go for the real deal.

That is, of course, unless you are one of those people who are particularly sensitive to caffeine. "I know people who, after a couple of sips of something with caffeine in it, feel awful. They're jittery, anxious, and their heart rate rises," says Temple.

Pretty much everyone else can enjoy their coffee hit guilt-free, any day of the week. ▮

Caffeine can pose a health risk in certain medical circumstances. If in doubt, consult a doctor

Jasmin Fox-Skelly is a freelance science journalist based in Cardiff, UK

Treasures of the underworld

Subterranean ecosystems are home to some of the weirdest creatures on Earth. But they aren't as safe down there as we had thought, finds **Aisling Irwin**

TOMMY AU PHOTO/GETTY IMAGES

A lava cave in Iceland is a tiny part of a vast, underground habitat found around the planet

ONE moment Stefano Mammola is standing in a mossy forest overlooking northern Italy's Po plain. The next, he has vanished through a hole little wider than his body, into the forest floor. With less grace, I clamber after him, landing in a pit 2 metres below. A tunnel ahead is the gateway to a 3-kilometre-long cave network. As I falter, Mammola, a cave biologist at the Water Research Institute in Verbania, Italy, encourages me with tales of an exotic spider living deep inside. It has cocoon silk that can stretch to more than seven times its length without breaking – outstanding even by arachnid standards.

Superstrong silk is just one of the ways life has adapted to Earth's most extensive and unexplored terrestrial ecosystem: the caves, fissures and tiny gaps beneath its crust. Scientists have spent the past few decades exploring these remote locations and cataloguing and probing the creatures within. Now they are raising the alarm.

Until recently, it was assumed that this subterranean life would sit out climate change relatively unaffected, in cool seclusion. But new research has shot down this belief. Warmth, drought, seasonal change and rising seas are all reaching into underground refuges, leaving their occupants uniquely stranded. Yet our ignorance of these fantastical creatures is vast. Mammola is so concerned that he has coordinated a project aiming to map the entire subterranean ecosystem of Europe, reveal what biodiversity is present and figure out where to prioritise conservation efforts. This weird and wonderful world is worth saving

not just for its own sake, but also because it is crucial to human survival.

Caves are defined, a bit anthropocentrically, as underground spaces into which humans can fit. Combined with smaller voids, they make up the subterranean ecosystem (there is also a submarine ecosystem beneath the ocean crust). Limestone karst, sandstone and cooled lava are richest in perforations, but most of the ground beneath us contains habitats at between a metre and 2000 metres depth. "We are only on the surface of a cheese that's full of small holes," says Rodrigo Ferreira at the Federal University of Lavras, Brazil.

Crawling, swimming and wriggling through these mostly pitch dark and often wet labyrinths are an estimated 50,000 to 100,000 species of spiders, millipedes, crustaceans, insects, bats, worms, snails and fish, plus bacteria, fungi and protists. Most remain undiscovered and undiscoverable. "What we can explore are the caves, but the habitat is much, much bigger than that," says Mammola. Some of its inhabitants, known as troglobites, can only survive underground. Others – cave-roosting bats, for example – are trogloxenes, living underground for a portion of their lives. Then there are troglophiles, including most salamanders, which are happy living both inside and outside caves.

In the past few decades, this world has opened up to scientists. Spectacular discoveries in Europe include those in Movile cave, Romania, where an entire food web was found living without light, complete with giant microbial mats, leeches, woodlice, a water scorpion and a snail. In Brazil, discoveries began to escalate more recently, says Ferreira. Brazilian scientists have formally described around 300 troglobites, but 1000 or so more await examination in freezers and cupboards.

Even well-known species can hold surprises. Mammola often encounters a spider called *Pimoa rupicola*. Despite being very common, until recently no one had noticed that it is, in fact, three species. One of these sports a spike protruding at right angles from the tip of its pedipalp (the spider equivalent of a penis), part of a lock and key mechanism that ensures it mates only with its own kind.

The spiders he and I are hunting are equally strange. But, as I slide down loose rocks under a slab of slimy granite, my claustrophobia is growing. Mammola, sensing I will never reach the depth required to encounter our quarry, shimmies ahead, disengages one from its web and returns. The bewildered-looking creature, *Troglohyphantes lanai*, has tiny scars where its eyes should be and improbably long legs, which may have evolved to accommodate the many sensory hairs it deploys to detect air currents, humidity and various chemicals – or perhaps just to elevate it above the water.

For cave-dwelling species, such remarkable features are the norm. Waiting in darkness for a scrap of biomass to drift in from outside has led to some extraordinary adaptations. Many species have lost characteristics that are indispensable above ground, including eyes and pigmentation. In temperate caves, cuticles, the external layer crucial on the surface to lock in precious moisture, have thinned. Changes aren't just skin deep. Cave creatures live slowly to save on calories. Mammola tells me the story of "Katrina", a spider inhabiting a well-studied cave that remained motionless on her web for a year, waiting for a fly to blunder in from outside. Reproduction can be similarly leisured. One cave spider mates every 19 years, laying at most four eggs – measly compared with the hundreds produced by many of its ›

FRANCESCO TOMASINELLI

Stefano Mammola and the cave spider *Meta menardi*, which produces cocoon silk that can stretch to over seven times its original length

overground counterparts. Slow metabolism can also mean a long life. The olm, a colourless, eyeless salamander, can live for a century.

Then there is the trick of swapping genitals. In 1997, Ferreira discovered a new genus of cave-dwelling insects, *Neotrogla*, but it was another 17 years before a colleague, Charles Lienhard at the Natural History Museum of Geneva, Switzerland, noticed that the females have a penis – known as a gynosome – and the males a vagina-like chamber. The female protrudes and retracts her gynosome, dipping it deeply into the male vagina to suck up his voluminous semen. She does this regardless of her fertility, says Ferreira. "It seems that the males are more efficient at gathering food and then their sperm becomes not only useful for fertilising eggs, but also a nutritious and important drink [for females]."

"Critically, this underworld also provides services to the world above"

Subterranean life furnishes us with more than mystery, however. It is a treasure chest of genetic information. The isolation and relative simplicity of communities provide a natural laboratory for studying evolutionary processes. Troglobites can even give insights into human health. For example, identifying the genes responsible for their eye degeneration has helped scientists understand the human disease homocystinuria, which causes loss of vision.

Critically, this underworld also provides services to the world above. Some 95 per cent of unfrozen fresh water is underground. The United Nations has estimated that more than half the world's population relies on groundwater for consumption and agriculture, and 50 per cent of surface ecosystems also depend on groundwater. The subterranean world acts like a giant utility system below us, says Mammola, a backstairs operation that stores, cleanses and transports water and plays a role in the carbon and nitrogen cycles.

David Brankovits, also at the Water Research Institute, dives into flooded caves to study these processes. He tells me about one such cave system under the Yucatán peninsula in Mexico, 1600 kilometres of which have been mapped. To reach this realm, he treks through the jungle to an unobtrusive hole in the ground and slips into its murky water. "As we dive down, the visibility becomes spectacularly clear," he says. These caves were thought to be "aquatic deserts" because the bedrock above them filters out everything except water. But that water turns out to contain dissolved organic matter from the forest, including the greenhouse gas methane, and this provides food for microbes, supporting a food web. This system purifies water, sequesters carbon and purges excessive nutrients such as nitrogen – then it seeps clean water into the ocean, a service previously thought to be the preserve of rivers. Without the life underground, says Brankovits, coastal waters would be at greater risk of severe degradation and much more methane would bubble into the atmosphere. "It really matters," he says.

Discoveries like this are making scientists increasingly alarmed at the rate of disappearance of the subterranean world – from destruction by mining, tunnelling and groundwater extraction, and as a knock-on effect of deforestation. Now there is the added realisation that global warming poses another challenge. "What I find fascinating is that people had been saying climate change will not be relevant underground," says Mammola.

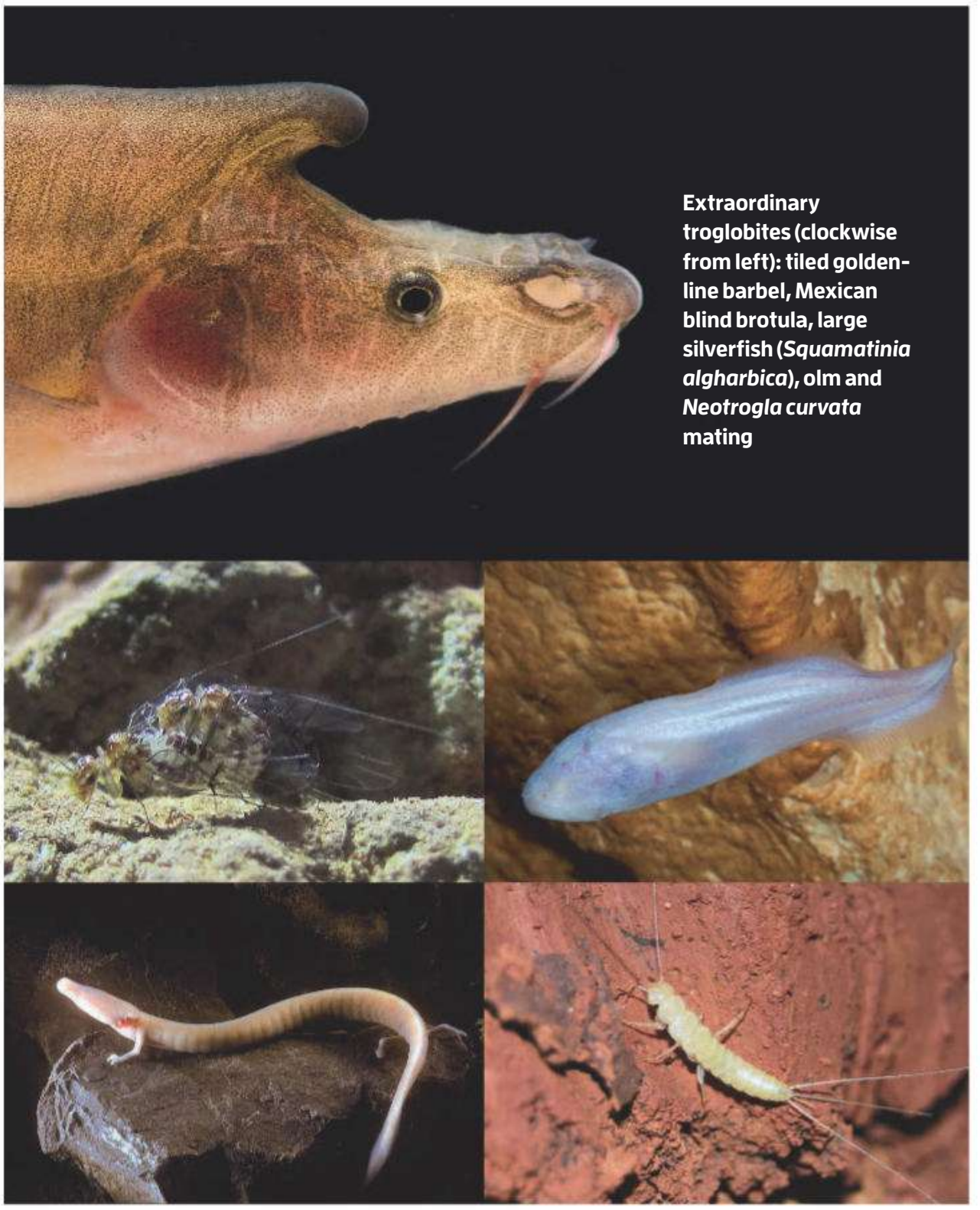
Two decades ago, Mammola was among the first to predict that cave temperatures rise in concert with those outside, but with a 20-year time lag. The finding, based on computer modelling, was hard to confirm due to a lack of temperature data, but in 2018 it was verified in 30-year records from a cave in Slovenia. Since then, researchers led by Ana Sofia Reboleira at the University of Lisbon, Portugal, have looked at caves in multiple locations and found that temperatures within each vary very little, but equal the average yearly temperature outside.

Recently, Mammola returned to 30 caves whose temperature he had measured a decade ago to repeat the experiment. He found an average increase of 0.5°C. He fears instrumental error and plans to take further measurements, but, if accurate, the finding could be a big deal for troglobites. "If you are adapted to stable conditions and have been living for generations in the same constant temperature, you probably do not have a lot of physiological mechanisms to cope with change," says Reboleira.

Can't stand the heat

Mammola and his colleagues have modelled the effect warming might have on eyeless, long-legged spiders of the genus *Troglohyphantes*. "Most of the species will really retract their distributions and even go locally extinct," he says. Experiments in the lab revealed that a rise of between 1°C and 2°C was often lethal. Other fauna may be more resilient, though. Reboleira is about to publish work showing that various cave-adapted animals die at 6°C above their average living temperature. And in other experiments, blind and wingless cave beetles endemic to the Iberian peninsula survived a quick exposure to 20°C (68°F). But their cells were stressed and damaged. "So maybe in the long term there will be other consequences that we don't know of," says Susana Pallarés at the University of Murcia, Spain, one of the researchers.

Cave dwellers might, of course, find a solution. "You need to hope that they will have the capacity for local adaptation in their DNA,"



CLOCKWISE FROM TOP: DANTE FENOLIO/SPL; CLAUDIO CONTRERAS/NPL/ALAMY; ANA SOFIA REBOLEIRA; NPL/ALAMY; RODRIGO LOPES FERREIRA

Extraordinary troglobites (clockwise from left): tiled golden-line barbel, Mexican blind brotula, large silverfish (*Squamatinia algharbica*), olm and *Neotrogla curvata* mating

says Mammola. One possibility is that the genes that would allow them to adjust to changes in temperature are merely switched off, rather than lost – something Mammola is planning to study. Another possibility is that the heat-stressed creatures will retreat deeper into their underground network (although food gets scarcer the deeper you go).

A further possibility is that humans could intervene. In Pennsylvania, conservationists drilled new entrances into old mines and railroad tunnels where bats roost to encourage upwards air flow, allowing heat to escape. Interfering in this way has been controversial, but it cut temperatures during hibernation, successfully slowing the growth of white nose fungus, which has killed over 90 per cent of three North American bat species.

Troglobites might also be relocated. Entire cave communities have been transplanted twice already, in Brazil and the US, to escape destruction from mining, says Mammola. Conservationists can offer temporary sanctuary, too. In Slovenia, when heavy rains wash olms into the open, scientists rehabilitate them in an underground lab and reintroduce them to caves within their species range.

Such measures may seem drastic, but cave biologists warn that we ignore the vertical dimension of climate change at our peril. Late last year, they called for groundwater and its inhabitants to be urgently conserved because they make up a "keystone ecosystem… an essential component of planetary health". Governments drawing up biodiversity plans have mostly ignored the underworld, they say. As a result, only 7 per cent of subterranean ecosystems globally are in protected areas.

This is where Mammola's mapping project comes in. The DarCo project, funded with €1.7 million from the European Biodiversity Project Biodiversa+, aims to chart the subterranean life of the entire continent. At the Water Research Institute, Adrià Bellvert shows me how DarCo is taking shape. With the click of a mouse, spots rain down on a map of Europe on his computer screen. This is the data being collected about which subterranean species have been found and where. He feeds it into a model that extrapolates to predict species distributions across undocumented regions. This is done using information on geology, precipitation and the extent to which the presence of one species predicts or excludes the presence of another. The next step, says Bellvert, is to apply sometimes ruthless reasoning about the feasibility of protecting each area. Places where extreme temperature rises are predicted or mining projects are planned may not be worth the effort – and it isn't always worth saving a place whose species differ little from another, already conserved region.

Protect and defend

The results, the DarCo scientists hope, will be used to inform regional and global conservation commitments, in particular the Natura 2000 network of protected areas in the European Union and the bloc's Biodiversity Strategy for 2030, which seeks to create protected zones for 30 per cent of its land and sea territories by the end of the decade. So far, only two-thirds of protected areas has been decided. The team wants to influence the remaining choices.

Protection can't prevent temperature rise, acknowledges Mammola. But it can reduce other environmental pressures that may drive a species over the edge. It can also shine a spotlight onto a long-ignored part of nature. Take Barrocal cave in Portugal's Algarve region. A hotspot for underground biodiversity, the local municipality bought the land above it in 2021 and is working with scientists to create a legal framework to protect the cave and its inhabitants and build a long-term monitoring station. "These are local initiatives, but that's also part of how you get to major things," says Reboleira, who is leading the project.

Persuading people to conserve something critically important but full of unknowns makes for hard work, says Mammola. But there is no time to wait. "It means accepting the predominantly undefined nature [of the underworld]," he says. "It implies, quite literally, operating in the dark." ▮

Aisling Irwin is a freelance journalist based in Oxfordshire, UK

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The science of baking

Melt in the mouth

A reluctant **Catherine de Lange** tries tempering for the first time and discovers the science behind gloriously glossy chocolate

Catherine de Lange is the editor of *New Scientist* and an avid baker

What you need

100 g (3½ ounces) dark chocolate (or more, depending on your decoration plans)

Cooking/candy thermometer
Acetate sheets (optional)

The science of baking appears every month

Next week

Dear David

WHEN it comes to birthday cakes, I am used to creating sweet, icing-loaded creations in the shape of Disney characters. These requests leave me unfazed, but my father, who is a dark chocolate aficionado, asked me to bake the cake for a big birthday lunch, which will require a different level of sophistication.

I have a wicked recipe for a flourless dark chocolate cake. But without flour, a cake has little structure, so this won't do for a celebration cake that needs enough layers to look grand and feed a crowd. Instead, I am going to make a standard chocolate cake and go wild with dark chocolate shards. The only problem is that I have never worked with chocolate before, as I have been put off by the complicated process of tempering.

Tempering chocolate involves melting and cooling it several times in order to change the composition of the crystals within. Get it right and your chocolate will be gloriously glossy, have a perfect snap to it and will melt in the mouth rather than in your hands (or on the cake).

Not only is the process laborious, but it also requires equipment (admittedly only a thermometer). Like any busy baker, the first thing I do is look for shortcuts, and it turns out that scientists are on the case.

In 2021, researchers isolated various parts of cocoa butter and tested their effects on tempering. They found two phospholipids – minor components of cocoa butter – that are usually removed in chocolate production can be added back in to chocolate in tiny proportions to produce the type of crystalline structure normally achieved through tempering. Sadly, the researchers don't specify how the humble home cook can achieve the same effect. Eggs are one source of phospholipid, so I consider experimenting with tiny additions of egg yolk, but decide this is more complicated than tempering itself.

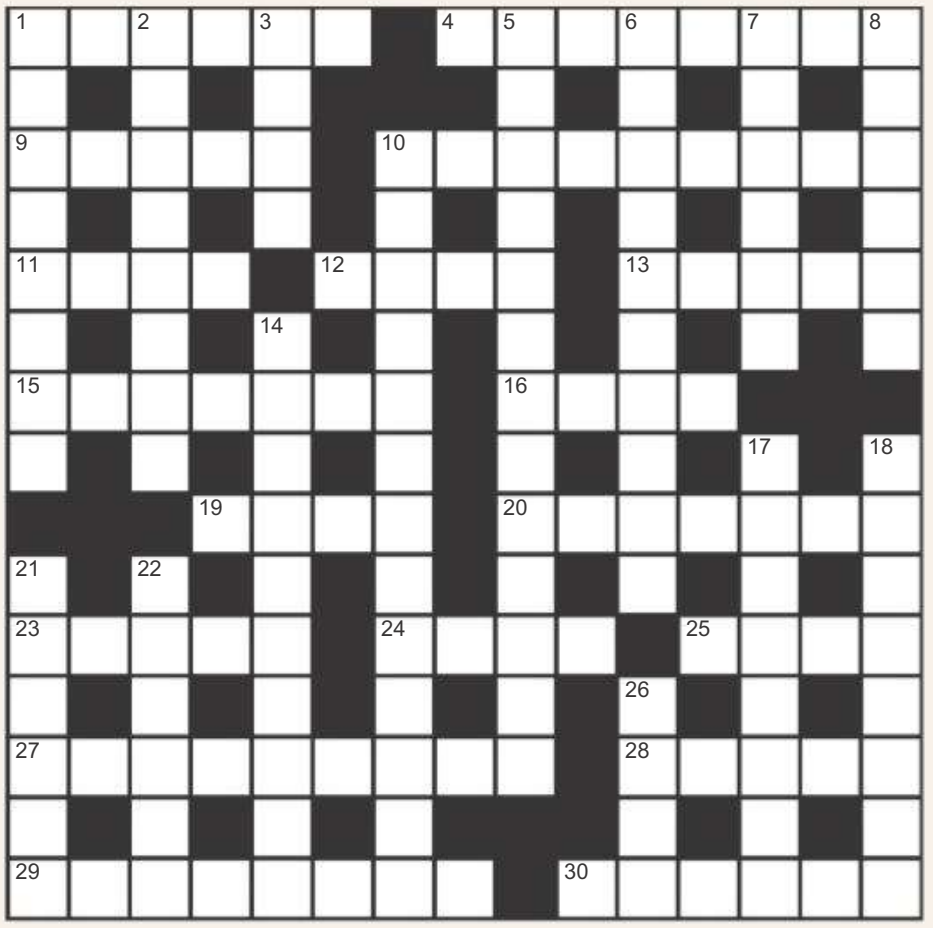
DORLING KINDERSLEY: WILLIAM REAVELL/ALAMY

Defeated, I embrace the task (and buy a thermometer). The fats in cocoa butter can take six different crystal forms, which all have their own melting point. We want to achieve the maximum amount of type V crystals, which melt at 33.8°C (92.8°F). Start by melting your dark chocolate to 45°C (113°F) in order to break down all the crystal forms. There are various ways to melt your chocolate, but, being French, my go-to is a bain-marie, or double boiler. Then, remove from the heat and gradually cool the chocolate to 27°C (80.6°F) by placing your bowl into a larger bowl of cold water and stirring. You will now have mainly type IV and V crystals. Finally, return to the bain-marie and heat again to 32°C (89.6°F) to get rid of the type IV crystals.

Your chocolate should now contain only type V, and be smooth and shiny and ready to mould. For dramatic shards, spread the molten chocolate onto acetate and, when cool, snap into irregular shapes. ▮

These articles are posted each week at newscientist.com/maker

Quick crossword #165 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Zerk (6)
4 *The Expression of the ___ in Man and Animals,* 1872 Charles Darwin work (8)
9 Tycho ___, Danish astronomer (5)
10 mg (9)
11 10^5, in Indian (4)
12 Elisha ___, inventor of the safety elevator (4)
13 Equine (5)
15 Study of alien spaceships (possibly) (7)
16 Egg-shaped (4)
19 Area (4)
20 Type of crystal growth (7)
23 Light device invented in 1960 (5)
24 Hearing organs (4)
25 Collaboratively edited hypertext document (4)
27 Aviation program (9)
28 Lubricated (5)
29 Bunsen ___, scientific Muppet (8)
30 Rubber (6)

DOWN

1 No (8)
2 Drifting aquatic organisms (8)
3 Vegetable in the genus *Allium* (4)
5 Hard sandstone (9,4)
6 Disorder of the eyelashes (10)
7 Model of the solar system (6)
8 Plastic explosive (6)
10 Dye and medicine, $C_{16}H_{18}ClN_3S$ (9,4)
14 Wave imaging in sections (10)
17 Genus of bacteria (8)
18 Tube (8)
21 Sodium hypochlorite, perhaps (6)
22 Compound also known as tribulin (6)
26 2^2 (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #266
set by Bethan Ackerley

1 In botany, seed pods that remain closed at maturity are known as what?

2 In what year was the US space station Skylab deorbited?

3 Herring bodies in the posterior pituitary gland store oxytocin or which other hormone?

4 What is the taxonomic rank between kingdom and class?

5 Knap of Howar and Skara Brae are Neolithic sites on which island group?

Answers on page 47

BrainTwister
set by Phil Lloyd
#34 Square dealing

If $a^2 + b^2 = c^2$, and a, b and c are three consecutive positive integers, what is the value of a? (You may know an example of a famous theorem that fits here.)

If $d^2 + e^2 + f^2 = g^2 + h^2$, where d, e, f, g and h are five consecutive positive integers, what is the value of d?

After that, the next two sequences in this family have seven and nine consecutive positive integers. They start with 21 and 36. What do you notice about the starting numbers?

The next sequence after that will use 11 numbers. What is the first one?

Solution next week

Life in space

If time changes as a result of the speed of space travel, do the cells in an astronaut's body still multiply at the same rate?

Ron Dippold
San Diego, California, US
It is all relative. The simple answer is yes for the astronaut, no for someone (relatively) stationary watching them. To the astronaut and anyone with them, their cells are still growing at the usual rate. Their hair and nails need to be cut just as often.

To an observer just sitting in a chair on Earth, though, the astronaut's cells will appear to be growing slower. The International Space Station (ISS) is travelling at about 7700 metres per second relative to us – the people up there are ageing 0.01 seconds slower per year than those of us down here because of that. But 0.01 seconds doesn't really register mentally, so let's kick it up a bit.

If the ISS were orbiting at 90 per cent the speed of light (not possible, but let's pretend), the Lorentz factor, or time difference, would be much higher. At this speed, the Lorentz factor would be 2.3, which means the astronauts

"If the space station were orbiting at 90 per cent the speed of light, the astronauts would age 43 per cent as fast as people on Earth"

would be ageing 43 per cent as fast as the people on Earth. At 99 per cent the speed of light, it would be 14 per cent as fast. To us, their hair and nails would be growing one-seventh as fast and they would be moving in slow motion. But to them, if they managed to avoid getting squashed against the walls or being too dizzy to eat, their hair and nails would be growing at the usual rate.

If you had 20-year-old twins and one of them somehow went up to the 99 per cent speed of light ISS and spent 10 years (for them) there before returning, their twin would be 90. This is known as the twin paradox – which isn't really a paradox, it is just Albert Einstein's special relativity at work. Even at slower speeds, this has been repeatedly measured and GPS satellites need corrections for it. It's real!

Alan Dix
Aberaeron, Ceredigion, UK
It is a common misconception that time "slows" as one moves faster.

Einstein said that time is what it says on the clock, or perhaps the astronaut's wristwatch. The core of special relativity is that there is no universal clock against which things run slower or faster. Time is individual and so we may get out of sync with our clocks depending on the route we take through space-time. The astronaut's cells will multiply at the same rate by their own clock, but, when they return to Earth, will have done so less than the cells of colleagues who stayed behind, because they took a "shorter" route.

Nick Canning
Coleraine, County Londonderry, UK
Yes: consider Ann and Bea, identical twin microbiologists each with an identical clone of an *E. coli* bacterium cell, kept under identical conditions. Ann stays at home and measures the rate of cell division of her sample. Bea takes her sample on a space trip near the speed of light. She also measures the rate of cell division in her sample.

At the end of Bea's round trip, the twins meet up again and compare measurements. They both find that they recorded the same rate of cell division, but Ann's cells (both the *E. coli* and her own) have divided more times than Bea's.

For Bea, less time has passed than for Ann; she has aged less between their meetings than Ann has due to the relativistic time dilation effect. This is a real phenomenon confirmed by many different experiments – for example, the half-life of radioactive particles in motion is longer than when they are at rest, as seen in accelerator experiments or in cosmic ray showers.

SHUTTERSTOCK/MAXX-STUDIO

This week's new questions

In a tin can **In a post-apocalyptic but non-nuclear world, how long would canned food remain edible?** ***Bob Gilbert****, Pender Island, British Columbia, Canada*

Which way? **Compared with a completely still universal reference point, how fast am I moving and in which direction?** ***Derek Johnson****, Moreton-in-Marsh, Gloucestershire, UK*

How long would canned food last in a post-apocalyptic world, if radiation weren't a problem?

Hard hitting

What happens when a hammer hits a nail? Do hammer electrons hit nail electrons? If not, what drives the nail in?

Eric Kvaalen
Les Essarts-le-Roi, France
In a sense, that is true. The electrons of the hammer repel the electrons of the nail, pushing them down a bit. That causes the nuclei in the nail to move downwards too, attracted by the nail electrons. Although the electrical effect travels down the nail at nearly the speed of light, that doesn't move the atoms much. It is only when a wave of motion, travelling at the speed of sound in metal, reaches any given point in the nail that the atoms there begin to move appreciably.

Paul Dormer
Guildford, Surrey, UK
It is wrong to think of electrons as being hard balls bouncing off each other. An electron is a very small packet of negative charge surrounded by an electromagnetic field. As such, electrons repel each other long before they make contact. It is similar to pushing

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Tom Gauld
for New Scientist

IS KEITH LATE AGAIN? DR. WILSON HATES LATENESS ALMOST AS MUCH AS SHE HATES HAVING THINGS IN THE LAB THAT HAVEN'T BEEN PRESERVED, CATALOGUED AND FILED.

the like poles of two magnets together. The closer two electrons are to each other, the greater the force pushing them apart and they never make contact. It takes something of the energy of a particle accelerator to get two electrons to actually collide.

About 50 years ago, a colleague wondered what happens if a fly crashes into a speeding train. Obviously the fly is squashed, but, he reckoned, at the moment of contact, both the fly and the train must be stationary. Again, electromagnetic forces prevent the atoms of the fly from making contact with the train.

Brian Spence
North Berwick, East Lothian, UK

Like many a parent, I used to embrace my children with a fatherly hug as a form of greeting after a period of absence.

This practice ceased a number of years ago after realising the answer to this reader's question. We now fist bump and simultaneously greet each other with the words "10 to the minus eight" – this being roughly the closest our fists will have got to each other, in metres, before the electromagnetic force repels the parent from the child.

"When we walk barefoot along a sandy beach, we aren't touching the sand but hovering just slightly above"

So no, the electrons in the hammer don't touch those in the nail – the momentum of the hammer is transferred to the nail by the electromagnetic force.

In exactly the same way, when we walk barefoot along a sandy beach, we aren't touching the sand but hovering just slightly above. Touch is an illusion created in our brain. This, of course, is the classical physics answer. I look forward to hearing the quantum answer: presumably it will require both hammer and nail to be present at the same time, and depend on whether the hammer owner has fed the cat.

Take a breath

How did marine reptiles such as ichthyosaurs breathe? (continued)

Stuart Henderson
Canberra, Australian Capital Territory

An interesting aquatic reptile is the Fitzroy river turtle, which is found in northern Australia. It draws water in and out of its cloaca (an excretory and sexual orifice), absorbing oxygen from it and expelling carbon dioxide from its blood, getting around 70 per cent of its oxygen needs this way. In short, it can breathe through its bum.

But there is an advantage for large marine creatures to only breathe air: it makes it easier to maintain a body temperature higher than the surrounding water, compared with constantly losing body heat to the water required to breathe. Adult leatherback turtles, for example, have been found with core body temperatures 18°C (32°F) above water temperature. ▮

Answers

Quick quiz #266 *Answers*

1 Indehiscent
2 1979
3 Antidiuretic hormone
4 Phylum
5 Orkney, off Scotland

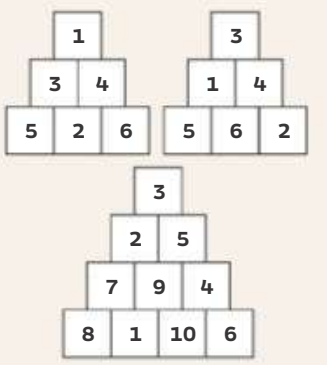
Cryptic crossword #142 *Answers*

ACROSS 1 Potato peeler, **8** Cathode, **9** Ozone, **10** Delve, **11** Twinkle, **12** Shyest, **14** Hex bit, **17** Antenna, **19** Spoor, **21** Sew up, **22** Plateau, **23** Eratosthenes

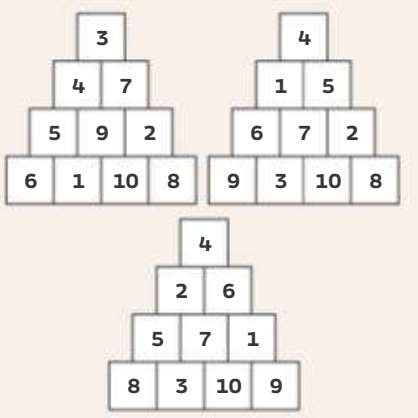
DOWN 1 Paced, **2** Totally, **3** Trope, **4** Plenty, **5** Ebonite, **6** Ebook, **7** Resent, **12** Sparse, **13** Sunspot, **15** Boolean, **16** Pampas, **18** Tower, **19** Staph, **20** Routs

#33 Number triangles *Solution*

The completed triangles are:



The other ways to fill a triangle with the numbers 1–10 are:



Morbid dating

If one craves morbid romance, one could, if one wished, write an algorithm to select an attractively morbid prospective mate or a recreational date.

Coltan Scrivner, the curiosity-driven inventor of the Morbid Curiosity Scale (Feedback, 19 November 2022), has looked into a new use for his tool. He and two colleagues, in a new study, explain that "Behavioral attraction predicts morbidly curious women's mating interest" in men with dangerous personalities.

They cite earlier research showing that those "women are aware of potential costs associated with such men". The new research aims to aid said women. It says: "Despite the potential costs of high-dark triad men, it could benefit morbidly curious women to upregulate their preference for such men to satisfy short-term mating goals."

The research doesn't pursue the obvious business potential here. Feedback envisions a new era of specialised morbid tool-making and tool use. Cheery days lie ahead, maybe, for the industry that originally was called "computer dating".

(For the curious, Scrivner has also created an easy way for you to measure where you lie on his scale: a free online Morbid Curiosity Test. Before starting it, you will be informed that "'morbid' does not mean the curiosity is bad – it simply refers to the fact that the topic is related to death in some way".)

Limits of curiosity

What are the limits of your curiosity? Is there a reliable, simple way to find out? Here is one possible test.

Feedback has a copy of a paper that Subhash Chandra Shaw and his colleagues published in *Medical Journal Armed Forces India*. The title of that research might tell you – by your reaction to it – something about yourself.

The paper is called "Missing anus: Do not miss it".

Twisteddoodles *for New Scientist*

OK Y'KNOW THAT EXPERIMENT I CANT GET TO WORK?
NOO
I POSTED ABOUT IT ON AN INTERNET FORUM LOOKING FOR SOME ADVICE
APPARENTLY SCIENCE HAS BEEN GASLIGHTING ME, OUR RELATIONSHIP IS TOXIC AND I DESERVE BETTER
I MAY HAVE POSTED IN THE WRONG FORUM
@twisteddoodles

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Consideration of items sent in the post will be delayed

Chatting politics

A few politicians seek success by being ultra-glib. In so doing, they achieve momentary plausibility.

Feedback notices a similarity between those politicians' shiny, hollow speech and the shiny, hollow text generated by ChatGPT and similar artificial intelligence computer programs.

Michael Townsen Hicks, James Humphries and Joe Slater at the University of Glasgow, UK, did a study called "ChatGPT is bullshit", which appears in *Ethics and Information Technology*. They argue that "describing AI misrepresentations as bullshit is both a more useful and more accurate way of predicting and discussing the behaviour of these systems". The team mentions a prime example of bullshit: a political candidate saying particular things only because the words might "sound good to potential voters".

Feedback admires the skill, if little else, of those politicians who, like ChatGPT, can utter endless streams of easy-to-swallow-though-not-to-digest patter. A few of the most successful of those ChatGPT-ish politicians, in several countries, also display a visual counterpart to their words – a just-fleetingly-plausible physical aspect of themselves. They adorn their heads with hair, or stuff that momentarily plausibly passes for hair, of ChatGPT-ish quality. There is, as yet, little published research about why and how that happens.

Not so trivial

Feedback continues the quest to compile a list of trivial superpowers. Aline Berry confesses and professes to having a trivial superpower that potentially isn't trivial.

She writes: "I believe I have a super power which I have taken for granted all my life. When someone complains that they have been looking everywhere for something, I usually find it within 5 minutes. Somehow, like Sherlock Holmes, I eliminate the obvious which they must have looked at and zero in on the missing item, which may be out in view but camouflaged in such a way that it is overlooked.

"In one instance lately, a friend had been frantically looking for her car keys 'all morning' and asked for my help. I stood looking around, realising it would be useless for me to go over everything, and asked her if she had looked in the refrigerator. Her eyes lit up. She had put her keys on top of something cold to remind her to take it with her and had promptly forgotten about it."

Another ability manifested in childhood: "I came to a new school several weeks late and was presented with a geometry problem. I had not previously taken geometry and did not know any of the rules, so I looked at the graph and put down the answer. It was correct. The teacher accused me of cheating and gave me a problem she had drawn, which no one could have seen before. I put down the correct answer again. She punished me by giving me 10 problems which I had to do the 'proper' way. Since I did not know what the proper rules were, I was glad when I got the news I would be going to another school."

Swirl of interest

Here is an exercise in dimensional scaling. Which is more powerful: a) a storm in a teacup or b) a tempest in a teapot? Experiment is the real way to settle the question. Please survey your colleagues (minimum of 50), then submit your tripartite findings (number of respondents, storms and tempests) to: Swirl of interest, c/o Feedback. ▮

Marc Abrahams

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